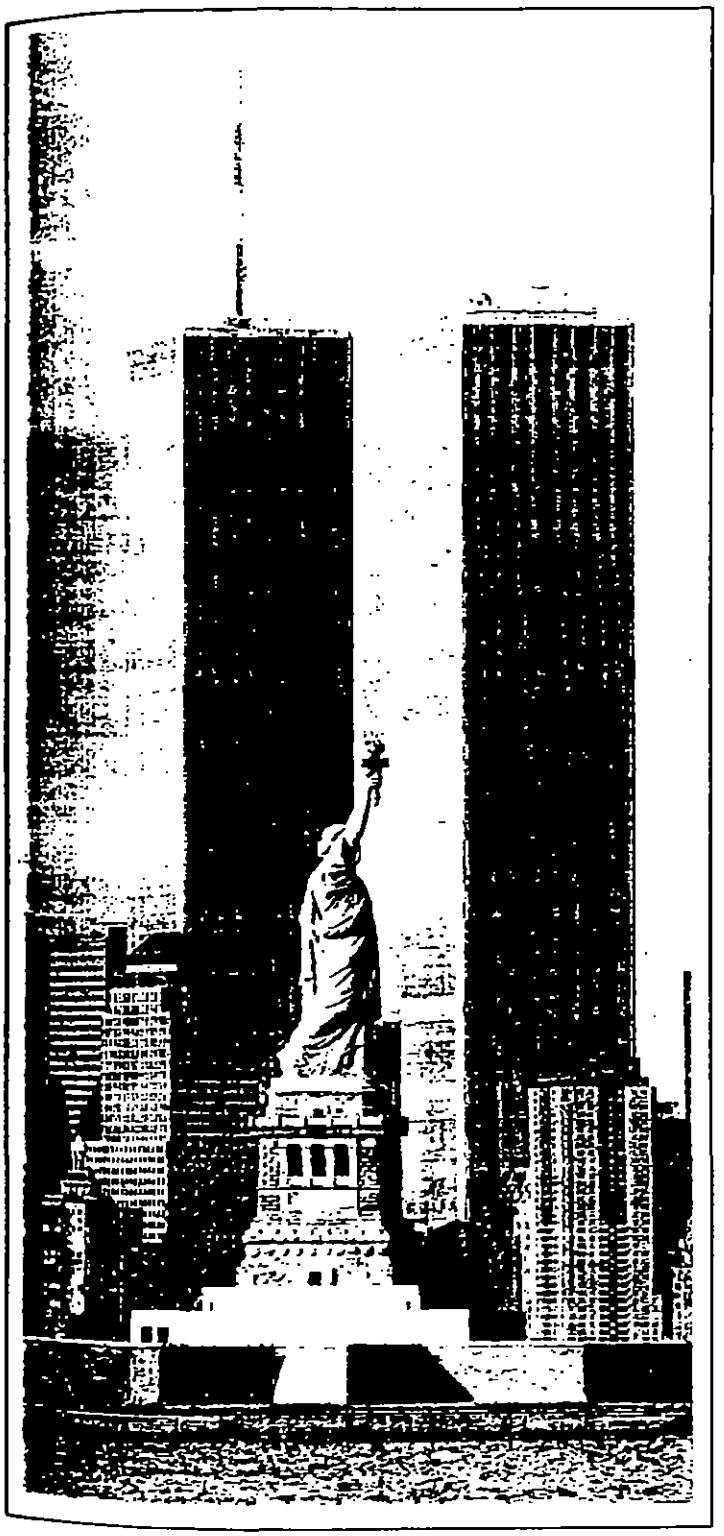

FINAL PRELIMINARY
REPORT

WORLD TRADE CENTER

GENERAL DESCRIPTION OF ALL BUILDING SYSTEMS AND THE CAPITAL PROGRAM

FOR
1, 2, 4 & 5 WORLD TRADE CENTER INCLUDING THE ENTIRE PLAZA CONCOURSE AND THE SUBGRADE

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SCOPE OF THE REPORT

The Scope of this report is to:

Phase I:

1. Identify and describe the mechanical, electrical, plumbing and structural systems in the World Trade Center Complex

Phase I of this report is based on PACO and Flack & Kurtz evaluation and analysis, based largely on their experience from working in the World Trade Center Complex, and their recollection of their configuration of systems. PACO also described the structural system.

Phase II:

2. Identify life expectancy of systems and equipment listed in the systems format.
3. Identify replacement programs and establish original expected life and remaining useful life after the program.
4. Identify Port Authority's maintenance philosophy, that exceeded in quantity and quality beyond normal maintenance, for increased life expectancy.

Phase II of this report was solely developed by PACO's evaluation and analysis is based largely on their experience from working in the buildings, their recollection of the configuration of systems, and their understanding of the scope and extent of capital and maintenance programs.

PACO and Flack & Kurtz also considered the Merritt & Harris and Property Solutions Reports on the World Trade Center Complex in the development of this document.

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DESCRIPTION OF SYSTEMS – PHASE I

General

The World Trade Center Complex consists of Tower A (WTC 1), Tower B (WTC 2), Southeast Plaza (WTC 4), Northeast Plaza (WTC 5), The Subgrade Floors and The Plaza Level.

The mechanical, electrical, plumbing installations and structural system for the WTC Complex, which are described hereafter consist of the following systems:

1. Mechanical Systems

HVAC Systems
Primary Heating
Secondary Water System
Air Distribution System
Condenser Water Supply System for Tenant Equipment
Building Automation and Control System
Elevator System

2. Electrical Systems

13.8 KV Electric Service
13.8 KV Power Distribution Center (PDC)
13.8 KV Feeders, Distribution System
Main Distribution Substations, 13.8 /0.48 KV
480 Volt Vertical Distribution System
208 Volt Vertical Distribution System
Horizontal Distribution System (Tenant Services)
Distribution System for Auxiliary Systems, including Motor Control Centers
Lighting System
Emergency Lighting System and Exit Sign System
Fire Alarm System and ADA Compliance
Security System
Communication System
Emergency Power Systems (Secondary and Tertiary)
Standby Power Generation System

3. Plumbing Systems

Domestic Water System
Domestic Sanitary System
Fire Standpipe System
Sprinkler System

4. Structural Systems

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1 Mechanical Systems

The following is a description of all the existing mechanical systems in the World Trade Center as of 9/11/01. It includes the systems as originally installed as well as all the subsequent improvements, if any. If a given system was improved, the nature of the improvement and the year of improvement were described for each system.

The HVAC system was upgraded subsequent to the 1993 bombing and chiller capacity was added as well as river water cooling capacity. This upgrade was implemented in conjunction with the electrical upgrade in order to support the WTC Complex capability of providing the tenants with a power density of 10 W/sq.ft. The original design of the WTC Complex allowed for a tenant power density of 4 W/sq.ft. only, which was inadequate for a leading signature Class A commercial building.

Other major improvements included the modernization of the elevator controls to solid state equipment and upgrades of the condensed water distribution system and the chilled water system for tenant equipment. In addition, a new unique security system and complex fire protection system were installed.

It must be emphasized that all systems had a level of redundancy, which allowed for a continuous maintenance of the system components to avoid failure of the system.

This redundancy and continuous maintenance of each equipment extended the life of each system well beyond the average life expectancy.

All systems are described in more detail hereafter.

1.1 HVAC SYSTEMS

Chiller Plants - Primary Cooling

The World Trade Center was served by two chiller plants, which were a base building refrigeration plant of 49,000 tons with a 1985, 5,000 ton upgrade and a supplemental refrigeration plant of 10,000 tons. The 49,000 ton plant was from the original installation (beginning service in 1970) and the 10,000 ton plant was installed after the bombing (beginning service in1995).

1.1.1 *Base Building Refrigeration Plant*

The original plant had seven (7) chillers, 7,000 tons each. The chillers were custom built by York™ for the World Trade Center. The chillers used R-22 as refrigerant. River water was used to

serve all cooling requirements for the refrigeration plant. Cu-Ni tubes were used on the condenser bundle.

The evaporator tube bundle was copper. The chiller plant was divided into high zone and low zone. The high zone evaporator was rated for 650 psi and water was pumped directly to the upper floors. The low zone chiller evaporator was rated for 300 psi. Chillers #1, 2, 3, 4 served the low zone. Chillers #5 and #6 served the high zone. Chiller #7 had the capability to serve both high and low zones. Chiller #4 and #5 had dual drive and compressor to operate at 7,000 ton (high) and 3,000 ton (low). This plant was built with considerable redundancy to accommodate the Port Authority's policy of preventative maintenance.

The low zone chillers served MER Rooms at B6, 7th floor and 41st floor in both Towers, and MER Rooms B1 and 9th floor in both WTC 4 & 5. The high zone chillers served MER Rooms at 75th. floor and 108th floor. The low zone had one 5,250 GPM Le Courtenay split case chilled water pump and four 10,500 GPM Le Courtenay split case chilled water pumps. The high zone had five 5,250 GPM Le Courtenay split case chilled water pumps.
This equipment was installed with the original building in 1970.

The plant was upgraded as follows:

- 1985 Low Zone: Installation of a 2,500 ton York™ Refrigeration unit
- 1985 High Zone: Installation of a 2,500 ton York™ Refrigeration unit
- 1993 Replacement of isolation valves

The chillers operated at 13.8 kV. The electrical power required was approximately 0.7 KW/ton.

The plant was damaged in the 1993 blast. However, after minor repairs the plant was restored and put back in service in May 1993. The same main vessels were used and the electrical motors were reconditioned. Also, the exterior piping, gauges, and the power centers were also replaced and the systems recharged.
It is estimated that the life expectancy of the plant would have been 50 years. Thus, by year 2025, the plant would have required major overhaul or replacement of the existing equipment. The plant became fully operational in 1973 and it is estimated that it would have had a life expectancy of 50 years due to the excellent maintenance of the system and its designed level of redundancy. The plant, which consists of seven (7) chillers, was designed to operate with five (5) chillers only, since it was considered that two (2) chillers would always be out of service for routine maintenance. The five chillers were required only during periods of hot summer days. Only twenty five percent (25%) of the time would more than three chillers be required to be operated at the same time.

1.1.2 Supplemental Refrigeration Water Plant

The supplemental refrigeration plant had a capacity of 10,000 tons with five (5) 2,000-ton chillers. The chillers were York™, with R-22 refrigerant, custom built for World Trade Center, because of the limited height of the occupancy. Also the chillers were rated for 650 psi and were able serve both high and low zones. The pipes from the supplemental plant were combined in a common header with the Base Building Refrigeration Plant.

The plant was provided with seven chilled water pumps and two booster pumps for river water recirculation.

The supplemental plant was used to provide winter chilled water needs and provide 24/7 needs of tenants in certain portions of the Towers. It was much more economical to operate a 2000 ton machine than a 7000 ton machine, if the incremental requirement was relatively small (i.e., 1000 to 2000 tons).

The chillers operated at 4.16 KV. The power requirements were approximately 0.7 KW/ton. The chillers had DDC controls with a York Code Pak control panel. The plant had a refrigeration leak detection system. The plant was supplied from a dedicated substation and transformers. This substation was supplied from two (2) 13.8 KV feeders originated in the Power Distribution Center.

The plant was upgraded as follows:

- 2000: Installation of twin plates and frame heat exchangers.
- 2000: Installation of a chilled water freeze protection system for the Windows on the World restaurant chilled water coil fan units located in the 108th floor MER.

The supplemental plant became operational in 1996 and was estimated that it would have had a life expectancy of 50 years due to the excellent maintenance of the system and its designed level of redundancy, similar to the Base Building refrigeration plant.

The distribution system throughout the Towers consisted of a low zone distribution system and a high zone distribution system. A 24" pipe running along its assigned zone served each system.

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1.1.3 Condenser Water, River Water Pipes and Pumping Station

The original system consisted of 60" and 20" river water lines that were used to exchange waste heat with the Hudson River in lieu of cooling towers. These lines ran to a pump house at river's edge through an easement with Battery Park City and served the original 7 – 7000 ton refrigeration plant, the expansion refrigeration plant and one tenant computer cooling system.

Due to the increased heat load, and as a result of the increased use of computers and other electronic equipment a large supply of condenser water for cooling year round was required. In past years, before the heavy computer utilization, the cooling system would run on the 20" in the winter allowing for maintenance of the 60". When the 60" line was required year round, allowing no time for its necessary maintenance, the new 66" river water line was installed to satisfy the requirements of the system. At any given time, only one set of pipes was used and the other was in standby maintenance mode. Thus, two (2) sets of 60" and 66" pipes were essential to the year round operation of the chiller plants.

The new 66" lines ran North across West Street, and then South in front of the Financial Center to the Pump Station. The installation of the 66" line required demolition and reinstatement of Battery Park City hardscape. The new 66" pipe was steel, was supported on piles and was provided with sacrificing zinc anodes every 10 feet. This waterline was installed during the period 1995 to 1999. It is estimated that its life expectancy would have been 50 years.

The condenser water pump station was located along the river in an underground facility. Initially there were eight Johnson vertical turbine 12,000 GPM pumps and two Johnson vertical turbine 800 GPM pumps (emergency pumps). They were replaced in 1997 with eight (8) constant volume pumps. Four (4) pumps had a capacity of 18,000 gallons per minute (GPM) and the other four (4) pumps have a capacity of 13,000GPM. Two (2) pumps with capacity of 3,500 GPM each were emergency pumps. The river water plant operated at a temperature differential of 17°F. The pumps had remote start/stop capability. It is estimated that the pumps life expectancy would have been 30 years, due to the level of redundancy and the continuous maintenance of the equipment. Fresh water was used to lubricate the seals. There were two (2) 5,000-gallon fresh water tanks for storage. Two new HCL tanks used for water treatment were installed in 1998. Their life expectancy would have been 30 years. Most of the pumping station and piping were outside the footprint of the WTC Complex.

1.2 Primary Heating

Con Edison steam was used for primary heating. The steam metering room housed pressure indicating valves and steam meters. Steam risers were extended through the Towers and tapped to preheat coils in air handling units and shell and tube heat exchangers. There were telescopic expansion joints in the steam risers. The steam risers supplied each mechanical room in WTC 1 and 2 at the following levels: B6, 7th floor, 41st floor, 75th floor and 108th floor. It also supplied the WTC 4 and 5 at the Mechanical Equipment Rooms (MERs) located at: B1 and 9th floor.

The condensate was piped to a condensate receiver. The receiver was arranged for heat recovery for preheating domestic water.
The system was as originally installed with only a few minor additions.
It must be noted that each Tower A and B and WTC 4 and 5 were provided with a redundant riser to assure continuous service and allow for continuous maintenance of the system. It is estimated that the life expectancy of the system would have been 50 years.

1.3 Secondary Water System

The secondary water system provided cooling and heating along the perimeter of the tenant floors. Water was delivered to the induction unit coil. The amount of water was regulated via a set of Honeywell regulating valves which were thermostatically controlled. Each system served two walls, namely North + West or South + East. There were a total 13 systems for Tower A or 13 systems for Tower B. Each system consisted of the following (the total number of component for Towers A or B is summarized):

TOWER COMPONENTS PER SYSTEM COMPONENTS	TOTAL
• Two split case Wieman Pumps 4L	52
• One shell and tube cooler	26
• One shell and tube steam heat exchanger	26
• One differential station	26
• One main supply riser	26
• One main return riser	26
• Twelve supply risers with isolation valves	312
• Twelve return risers with isolation valves	312
• One expansion tank	26
• Twenty four Honeywell regulating valves (2 walls)	9,120
• Sixteen thermostats	8,080
• Seventy two induction units	27,360

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There were a total of two (2) systems for WTC 4 and two (2) systems for WTC 5. Each system consisted of the following (total number of components for WTC 4 and 5 is also summarized):

WTC 4 or 5 COMPONENTS PER SYSTEM	TOTAL
• Two split case Wieman Pumps 4L	8
• One shell and tube cooler	4
• One shell and tube steam heat exchanger	4
• One differential station	4
• One main supply riser	4
• One main return riser	4
• Thirty supply risers with isolation valves	120
• Thirty return risers with isolation valves	120
• One expansion tank	4
• Sixty four Honeywell regulating valves (2 walls	720
• Forty thermostats	480
• One Hundred and Eighty induction units (2 walls)	2,060

For the systems as originally installed, it is estimated that the life of the components would have been 50 years. Pumps and heat exchangers were maintained or replaced on regular basis to assure the integrity of the system.

1.4 Air Distribution System

Constant volume central built up air handling units were located in the Mechanical Equipment Rooms (MERs) at B6 level and 7th, 41st, 75th and 108th floors in WTC 1 and WTC 2. The air handling units were divided into 5 zones, one in each quadrant, serving tenant floors within the zone. The units had 100% outside air economizer capability. The units had bag/cartridge filter media, steam preheat coils, cooling coils and fan sections. The control systems were (pneumatic) start/stop, temperature monitoring, and freeze protection, and had optimization, temperature reset and other energy saving features. The control room in the basement had start/stop capability. All systems had freeze protection circulation pumps.

The designation of the units used in each MER of WTC 1 and WTC 2 was as follows:

- ACS: Air Conditioning Supply Fans
- ACR: Air Conditioning Return Fans
- EX: Exhaust Fans
- VS: Ventilating Fans
- T: Transfer Fans

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The zones within each Tower A and B were as follows:

- Zone 1: B6 MER to B1
- Zone 2: Lobby to 24th. floor (includes 7th. floor MER)
- Zone 3: 25th floor to 58th. floor (includes 41st. floor MER)
- Zone 4: 59th. floor to 91st. floor (includes 75th floor MER)
- Zone 5: 92nd. Floor to 108th. floor MER

The total number of units per zone and per WTC 1 or 2 were as follows:

ZONE	MER	ACS	ACR	EX	VS	T
1	B6	5	5		13	4
2	7th	14	13	8		
3	41st.	16	12	10		
4	75th.	16	12	10		
5	108th.	19	9	16	1	
Total WTC 1 and WTC 2:		140	102	88	28	8

(Numbers from Table were doubled for total of WTC 1 and WTC 2)

The designation of the units used in each MER of WTC 4 and WTC 5 was as follows:

- ACS: Air Conditioning Supply Fans
- ACR: Air Conditioning Return Fans
- EX: Exhaust Fans
- ASOA: Auxiliary Service Outside Air Fans
- SPILL: Spill Air Fans

The zones within each Tower A and B were as follows:

- Zone 1: 3rd floor to 9th floor
- Zone 2: B1 to 3rd Floor

The total number of units per zone and per WTC 4 and WTC 5 were as follows:

ZONE	MER	ACS	ACR	EX	ASOA	SPILL
1 (WTC 4)	3rd +9th floors	13	9	14	3	2
1 (WTC 5)	Plaza to 9th	17	12	6		
2 (WTC 4)	B1 to 3rd	8	5	2		
2 (WTC 5)	B1 to Plaza	4	4	6	8	6
Total WTC 4 and WTC 5		42	30	28	11	8

In 1999/2000 an aggressive maintenance program was undertaken and all fans in the Towers and WTC 4 and 5 were rehabilitated and/ or replaced to bring the system to an excellent condition. Thus, the system was only one year old and its life expectancy would have been 20 years.

1.5 Condenser Water Supply for Tenant Equipment

The tenant cooling system for Towers A and B consists of 10 sub-systems. Two sub-systems 1 and 2 were installed initially with the base building between 1970 and 1976. Each included:

- Three (3) Shell and Tube Heat Exchangers
- Two (2) Case Wieman 8L pumps 1400 GPM

In 1977 Sub-Systems 3, 4, 5 and 6 were added. Each included:

- Four (4) Shell and Tube Exchangers
- Two (2) Split Case Wieman 4L Pumps 600 GPM (except for sub-system 3 speed is 2000 GPM)

In 1983 Sub Systems 7, 8 and 9 were added: Each included:

- Two (2) Shell and Tube Heat Exchangers
- Two (2) Split Case Wieman 8L Pumps 2000 GPM
- Three (3) Heat and Frame Heat Exchanger

In 1993 Sub System 10 was added. The system was a glycol system and it included:

- Seven (7) Fans
- Ten (10) Coils
-

The Sub Systems were upgraded as follows:

- 1995: Sub System 1 and 3 were provided with one (1) additional redundant chilled water shell and one (1) heat exchanger.
- 1995: Sub Systems 1 and 2 were provided each with two (2) additional Wieman Split Case Pumps 8L 12,000 GPM and two (2) new heat exchangers. An additional riser was installed for sub system 1.
- 1995: Sub System 10 serving Dean Witter floors was provided with one (1) plate and frame heat exchanger, three split case pumps, seven (7) vane axial fans, and ten (10) cooling coils.
- 1997: Sub Systems 7 and 8 were provided each with four (4) additional Wieman split case pumps 8L, 12,000 GPM, one (1) river water heat exchanger and two (2) additional plate and frame heat exchanger.
- 1998: Monitoring System to the Emergency Command Center.
- 1998: Additional Condensed Water risers, 10" pipes were provided for the tenant needs (one for each the low zone and the high zone).
- 2001: Sub Systems 1 and 2 were provided each with two (2) river water shell and tube heat exchangers, four (4)

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split case pumps, one (1) chilled water plate and frame heat exchanger

It is estimated that the life of the system would have been on the average 25 years. The system would have continued to be changed constantly as the tenants' requirements for Condenser Water increased.

1.6 Building Automation and Control System

The original central Building Management and Control System (BMCS) included a pneumatic local control panels with remote start/stop feature, served by a Honeywell 2000 system for all the HVAC equipment with the exception of the refrigeration plant. The system was upgraded in 1982 with a new hard wired manual start stop system which was installed at 1 WTC B2 Level. It is estimated that the life expectancy of this system would have been 50 years. An additional control system was provided for all the fans, pumps and heat exchangers. This system, which was installed by Honeywell, as an upgrade of a Controller RP908 with switching relays, sequencers and pneumatic relays. The combined system was upgraded in 1993 with new pneumatic controls. It is estimated that the life of the system, before an upgrade or replacement would have been 20 years.

1.7 Elevator and Escalator Systems

The World Trade Center elevator and escalator system contained 240 local, shuttle and freight elevators and 63 escalators and support equipment in One, Two, Four and Five World Trade Center, including the Concourse and subgrade levels. Their were165 local elevators and 46 shuttle elevators that served WTC 1 and WTC 2, as per Table 1.0:

Elevators/Escalators Summary Table 1.0

Designation	Number
WTC 1	
Local Passenger Elevators	72
Local Freight Elevators	4
Shuttle Passenger Elevators (Passengers and Freight)	17
Shuttle Service Elevators	6
Escalators	10
WTC 2	
Local Passenger Elevators	72
Local Freight Elevators	4
Shuttle Passenger Elevators	17
Shuttle Service Elevators	6

Escalators	10
Others	
Local Passenger Elevators	36
Local Freight Elevators	6
Escalators	43

There were also 57 escalators, many of which connected the concourse and the WTC PATH mezzanine. Much of this equipment, before the recent complete modernization, had been operational for more than 25 years and represents technology that was more than 30 years old. The World Trade Center elevators and escalators were manufactured and installed by Otis Elevator Company. The modernization of elevators, which took place during the period 1995 to 2001, consisted of the following:

1.7.1 Elevator Cab Replacement Program (Marble Cabs)
1.7.2 Elevator Control Modernization
1.7.3 Mechanical Elevator Upgrades

1.7.1 Elevator Cab Replacement Program

Upgrading of cabs included new cab interiors, finishes, a new communication system, new position indicators, anti-contact door openers and general rehabilitation work. The cab interior finishes included marble on a honeycomb aluminum backing with chromed stainless grab bars and newly carpeted floors. The shuttle cabs were all marble wall with stainless steel ceiling; the locals were provided with enamel walls with marble trim.

1.7.2 Elevator Control Modernization

The obsolescence of the original controls equipment created the need for a new solid-state controls system to improve waiting times, primarily by increasing elevator group efficiency. The original dispatching equipment employed outdated relay and transistor logic, and operated by assigning each elevator in an elevator bank to a service zone (typically two floors or the lobby). When a hail call was registered, the dispatching system assigned it to the corresponding zone elevator. If that elevator was unavailable, the system did not dispatch another elevator. Rather, it waited for an elevator to pass through the zone to answer the call. Only if there was an exceptionally lengthy delay (60-90 seconds) would the dispatching system assign the call to another elevator. In contrast, the new elevator dispatching systems provided for an estimated time of arrival (ETA) strategy, which analyzed all elevators in a group with respect to their location and other car calls and stops. The elevator with the shortest ETA (which is not necessarily the nearest car in terms of distance) was then assigned to newly registered hall calls. These dispatching assignments were continuously updated, as the system constantly recalculated ETAs and reassigned elevators as appropriate. The system utilized solid-state controls and microprocessor-based technology.

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1.7.3 Mechanical Elevator Upgrades

The elevators were constantly upgraded by replacing cables and worn out equipment. This was accomplished through a very rigorous preventative maintenance program with an outside contractor. Mechanical upgrades included cable replacement, vibration monitoring used as a guide for rail replacement and straightening, as well as code and other major and minor maintenance programs.

2. Electrical Systems

The following is a description of all the existing electrical systems in the World Trade Center as of 9/11/01. It includes the systems as originally installed as well as all the subsequent improvements, if any. If a given system was improved, the nature and the year of improvement is described for each system. In addition, we explain the maintenance program for each component and estimate its remaining expected life.

The 13.8 KV and 480 Volt electrical distribution systems were upgraded during the period 1990 to 2000 to support a power density of 10 W/sq.ft., as compared to the original design of the Complex, which provided for a power density of only 4 W/sq.ft. The WTC Complex peak demand was recorded to be 90 MW during summer periods of high temperature and humidity. This was consistent with the 10 W/sq.ft required for the WTC Complex. It should be noted that the original design of the WTC Complex electrical systems couldn't have supported this load.

During the period 1995 to 2001, the WTC Complex was also provided with a modern, complex Fire Alarm System and with a first of its kind Security System.

In addition, the emergency power and standby power systems were also upgraded during the last decade. The lighting system was also replaced and upgraded with modern technology components.

13.8 KV Electric Service

The 13.8 KV Electric service originated from the Con Edison substation located at the street level of World Trade Center 7. It consisted of eight (8) feeders designed to support a capacity of 200 MVA, consistent with the requirements of a 10W/sq.ft distribution system operating under second contingency constraints. The feeders were sized at 2 x 1000 MCM Copper. The feeders supplied a Power Distribution Center (PDC) located in the Subgrade of the WTC Complex.

These new feeders were installed in year 2000 - 2001. The upgrade also involved the rehabilitation of the deteriorated concrete truck dock and parking slabs supporting the feeders, rerouting of new 5" conduits through

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this slab and pulling the new 2 x 1000 MCM cables from the Con Edison Substation to the Power Distribution Center.

The system life expectancy was 50 years, since the system, which was new, would have never operated at full load. Thus, its operating temperature would have been well below the rated temperature.

2.2. 13.8 KV Power Distribution Center

The Power Distribution Center (PDC) was located in a fire-rated switchgear room. It consisted of eight (8) 15 KV class Switchgears equipped with 48 vacuum circuit breakers (6 breakers per Switchgear – 1 main breaker and 5 distribution breakers). This Power Distribution Center supplied all the 13.8 KV feeders, which distributed power throughout the WTC Complex. Forty-one (41) original breakers were replaced in 1993 and seven (7) original breakers were replaced in 1998, with new 1200 Amp.15 KV Class, draw-out, vacuum breakers. Replacement of breakers also included their relaying protection.

The life expectancy of these breakers was 50 years. The breakers were maintained in accordance with a yearly program following the manufacturer's recommendations. Used parts were replaced as required on a regular basis. The relays were tested and exercised on a yearly basis.

2.3 13.8 KV Feeders, Distribution System

The Towers A and B were supplied from sixteen (16) feeders, 8 feeders per tower, routed vertically through 2 shafts per tower. Each shaft housed 4 feeders, which supplied the Switchgears and Transformers located in the Mechanical Equipment Rooms (MERs) at the 7th, 41st, 75th and 108th floors. These feeders were sized at 500 MCM copper up to the 41st floor MERs and at 250 MCM aluminum from the MERs located at 41st floor to the 108th floor.

The feeders between the PDC and the 41st floor were replaced in 1993-1994.

Seven (7) feeders supplied the refrigeration room housing the 7 – 7000 tons chillers. They were replaced in 1993 subsequent to the 1993 bombing, with 350 MCM feeders.

Two (2) feeders, sized at 350 MCM were installed in 1995 to supply the new refrigeration plant housing the 5 –2000 tons chillers.

Six (6) feeders supplied the subgrade substations and the WTC 4 and WTC 5 substations.

Two (2) feeders supplied the Dean Witter substation located at the 41st floor of Tower B.

The remainder of the feeders supplied the Marriott Hotel, the Customs House and other ancillary equipment.

The life expectancy of the new feeders described above was 50 years.

2.4 Main Distribution Substations, 13.8/0.48 KV

- Main distribution substations were located on the 7th, 41st, 75th and 108th floors of each Tower. Two substations were located in the Mechanical Equipment Rooms (MERs) on each of these floors designated North and South substations. Each substation consisted of four transformers, which were networked on the secondary. Each was supplied by one of the 13.8 KV feeders. The capacity of two transformers provided the required power under second contingency operation. (The loss of two transformers allowed the collector bus to continue operating at full load). The substations located at the 7th floor and 108th floor served 16 floors, while the substations located at the 41st floor and 75th floor supplied 32 floors (16 up and 16 down).

- The original substations consisted of (4) 1500 KVA 150°C rise, FPE transformers with network protectors connected to a common collector bus. They were located at the 7th floor and 108th floor of each Tower and the 41st floor of Tower B. The capacity of these substations was 3000 KVA under second contingency.

- New substations were installed on the 75th floor of each Tower and the 41st floor of Tower A in 1996 and 1997. The new substations consisted of (4) 2000/2667/3325 KVA transformers with temperature rise ratings of 80/80/150°C with fan assisted cooling. These substations were arranged with network protectors connected to a common collector bus with normally closed circuit breakers that allow the bus to be isolated for maintenance purposes. The capacity of these substations was 6650 KVA under second contingency, thus allowing for delivery of 10 W/sq.ft. These substations had a regular ground bus connected to the building steel and an equipment ground bus. Ground faults were monitored within each compartment of the substation and isolated instantaneously, by tripping the adjacent breaker or breakers. The substation was isolated from ground, making each vertical section an independent grounding entity, protected by relays connected to the equipment ground bus. Incoming steel conduits were also isolated from the switchgear steel to enable the operation of the ground fault protection downstream.

- On the 41st floor of Tower B, Dean Witter, who occupied the lower half of Tower 2, had installed a substation in 1989, which consisted of four (4) transformers arranged in a similar configuration as the new substation described here above. The difference was that only

two (2) 13.8kV feeders were provided to supply these transformers (two transformers per feeder). This substation was dedicated to Dean Witter floors (8 – 40) in Tower B.

- On the 108th floor of Tower A, a new substation had been installed in 1998, consisting of four (4) transformers arranged similar to the new substation described above. This substation was intended to supply tenant needs as well as elevators in the upper part of the Tower A.
- The two (2) substations in the sub-grade and the two (2) substations in buildings 4 and 5 were the original substations with 4-1500 KVA transformers.

Substation Summary Table 2.0

	Substation Vintage			Capacity	
MER Location	Tower A	Tower B	Floors Supplied	KVA in 2nd Contingency	W/sq. ft.
7th Floor	Original (2)	Original (2)	8 – 24	6,000 for each tower A and B	11.7
41st Floor	New (2)	Original (2)	25 – 57	Twr. A: 13,300 Twr. B: 6,000 up 13,300 down	12.9 11.7 up 17.5 dow Dean Witter
75th Floor	New (2)	New (2)	58 – 92	13,300 each tower A and B	12.9
108th Floor	Original (1) & New (1)	Original (2)	93 – 108	Twr. A: 6,000 +13,300 Twr. B: 6,000	17.5 11.7

*Available under second contingency

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The substations operated at a load well below their full capacity, since they were designed for second contingency operation. Thus, both the "original" and the "new" substations had life expectancies of 50 years, with the new probably longer due to these operating conditions. A comment in Merritt & Harris that the main electrical sub-stations were not compliant with New York City Code is misleading – the sub-stations were unique for high-rise buildings and designed in the same manner as Con Ed designs its large sub-stations.

The original substations were installed with the original building equipment in 1970. The new substations were installed as follows:

- 1989 (Dean Witter – 1 substation)
- 1996 – 1997 (41st and 75th floor Tower A and B – 6 Substations)
- 1998 (108th floor Tower B -1 substation)

In addition, the Port Authority was conducting an intense maintenance program and maintenance evaluation program on all substations and also monitoring the eventual degradation of the insulation, with power factor tests performed every three years. The latest power factor tests on the original substations and transformers showed an insignificant degradation of the insulation. The latest power factor tests on the new substations showed no degradation of the insulation.

2.5. 480 Volt Vertical Distribution System

The original vertical distribution in the Towers consisted of 4000 Amp. FPE bus ducts, which were distributing power to the tenant floors at 480/277 Volt. A fused plug-in disconnect switch, rated 200 Amp or 400 Amp was provided in each electrical closet at each floor. There were two 4000 Amp risers in each Tower and two electrical closets on each floor. Each electrical closet was supplied from one of the risers. To increase the capacity of the existing bus duct, to match the capacity of the new substations and add flexibility for tenants located at the upper zone served by a new substation, new 4000 Amp bus duct risers were added in 1998. In both Tower A and B, four (4) bus ducts rated 4000 Amp were added for all 32 floors served by the new substations located at the 41st floor and at the 75th floor (16 floors up and 16 floors down). The tenants located at the first 8 floors were connected to the existing bus, while the tenants located at the next floors were connected to the new bus duct, via new fused plug-in disconnect switches. The life expectancy of the bus duct, "original" or "new," was 50 years, since its 4000 Amp nominal rating was well below its operating current. The new bus duct was installed between 1996 and1998. The original bus duct was installed with the original building equipment in 1970.

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2.6 208 Volt Vertical Distribution System

At each substation, two (2) 500 KVA transformers were provided for the 120/208 volt vertical distribution system (total of 16 transformers). The transformation took place from the existing 480/277 Volt system. The transformers supplied the two 4000 Amp risers, which were in each Tower (total of 4 risers).

They served the two electrical closets located on each floor to distribute power to the tenant floors at 208/120 Volt. A plug-in disconnect switch, rated 200 Amp or 400 Amp was provided in each electrical closet at each floor. The power density available equaled to approximately 2 W/sq.ft. Where tenants required additional 120/208V power, they supplemented with their own transformers supplied from the 480/277 Volt system.
The life expectancy of the original bus duct was 50 years, since its 4000 Amp nominal rating was well below its operating current. This bus duct was installed with the original building equipment in 1970.

2.7 Horizontal Distribution System (Tenant Services)

Each electrical closet on each floor (2 per floor) was provided with a power distribution panel at 480/277 Volt to supply all necessary loads on the floor, including lighting, which was supplied at 277 Volt. The distribution panel had a split bus for emergency circuits activated via a transfer switch. The emergency circuit, which supplied the essential loads on the floor, was supplied from the emergency riser, which is connected to the emergency generator system. The receptacle system, at 120/208 Volt was supplied from each of the 208 Volt vertical risers, via another distribution panel. Tenants were providing the floor wiring as required in accordance with their particular layout. The life expectancy of the distribution panels was 40 years. They were installed with the original building equipment in 1970.

2.8 Distribution System for Auxiliary Equipment, including Motor Control Centers

Each Mechanical Equipment Room in the Towers is provided with two (2) Motor Control Centers, serving all ancillary equipment (total of 16 motor control centers). There were four (4) additional Motor Control Centers in the Subgrade and four (4) additional Motor Control Centers for WTC 4 and WTC 5. Each motor control center had, on the average, 24 combination starters rated between 100 Amp and 400 Amp. Each combination starter supplied the designated equipment, via wiring sized in accordance with the load nameplate.
The life expectancy of the motor control centers was 40 years. They were installed with the original building equipment in 1970.

2.9. Lighting System

The original lighting system consisting of lighting fixtures equipped with four (4) 40 watt fluorescent lamps and electromagnetic ballasts, was progressively replaced with fixtures equipped with either 2-T8 32 W lamps and electronic ballast or 2 lamps biax and electronic ballast. Approximately 90% of the initial

fixtures were replaced during the period 1990 to 2001. The power density of the lighting was reduced from 4 W/sq.ft to 1.5 W/sq.ft., for a total reduction of about 8 MW for the entire WTC Complex. On the average, on each floor, there were 600 fixtures 2' x 2', for a total of about 150,000 for the entire complex, including the subgrade and WTC 4 and WTC 5.
The life expectancy of the lighting fixtures was 20 years.

2.10. Emergency Lighting System and Exit Sign System

The emergency lighting system was upgraded in 1993, subsequent to the 1993 bombing, by providing 2500 fixtures with battery packs in the staircases. In addition, all elevators were provided with emergency lighting, also backed up by a battery pack. There was a total of 244 elevators, or 244 elevator emergency fixtures for the entire WTC Complex. The initial exit sign system, illuminated with fluorescent lamps, was replaced with modern LED illuminated exit signs, with a consumption of 1.5 W per sign. This represents a reduction of about 14 W per sign. The program, which replaced about 5000 exit signs during the period 1997 to 2000, was implemented for the entire WTC Complex. The life expectancy of the fixtures and exit signs was 20 years. The life expectancy of the battery packs was 10 years. Therefore it would have been expected to replace the battery packs once over the life of the lighting fixture.

2.11. Fire Alarm System

The existing fire alarm (FA) system as manufactured by American Multiplex System, was replaced during the period 1996 to 2001 with a new decentralized system which included six Independent FA sub-systems as follows

- 1 WTC, 2 WTC, 4 WTC, 5 WTC, Concourse Level, and Sub Grade Levels. Each of the six systems was linked to a Network Command Center (NCC), located in the Fire Command Station (FCS) at the lobby of each of the four buildings. In addition, remote NCCs were installed in buildings 4 & 5 to backup each other, Sub Grade and Concourse main and remote NCCs in buildings 1 & 2 respectively, and 2 WTC remote NCC in 1 WTC. Furthermore, back-up NCCs for all six systems were installed in the new Operation Control Center (OCC), so if there was an emergency, the entire WTC FA system could be monitored and controlled from a safe remote location.

- Each of the NCCs was connected to a dedicated logging printer providing a sequential log of events and operator actions. Additionally, a color graphics software was installed in the new FA system so that in the future, when the design of the FA system were completed and floor plans (for the entire WTC complex) indicating the location of all FA devices were available, a color laser printer could be used to print graphic screen images. In the

event of an alarm, a floor plan with the exact location of the active device would be displayed so that the response team could locate the problem area easily and act accordingly.

- To enhance the integrity and reliability of the new FA system, a Style 7 Network wiring scheme was chosen, which included two additional independent network risers installed in two additional rigid conduits (totaling three conduits), at different locations (fire alarm closet, and two separate stairways). This scheme of wiring would accommodate any type of circuit malfunction (short or open) in any section of the network risers. Additionally, the network risers utilize #14 AWG Teflon cables (twisted pair, 600V, 200°C).

- Furthermore, the Pyrotronics NCC Global/Local (NCC-G/L) Fiber Optic Token Ring LAN, which operated independently of both the MXLV network and the RS-485 style 7 network, allowed each NCC on the LAN to monitor/control any combination of the six FA systems. The Fiber Optic cables were installed in rigid conduits and ran in a closed ring topology around the entire WTC complex. The ring was provided with self healing characteristics in the event of damage of the Fiber Optic assembly.

- The following systems/devices were used to bring all occupied areas up to full conformance with all applicable codes:

  - Wall mounted strobe units were installed in all corridors, bathrooms, common areas, and all occupied tenant spaces.
  - Ceiling mounted speakers were installed in all corridors, bathrooms, common areas, and all occupied tenant spaces.
  - Addressable area smoke detectors were installed in all base-building electrical and telephone closets, mechanical rooms, elevator machine rooms, and in elevator lobbies for elevator recall. Additionally, duct mounted smoke detectors and area detectors installed in front of the return/supply air grills were installed for fan shut-down.
  - Pull stations were installed next to each stairway and in the main exits in the main lobbies.
  - All existing sprinklers tamper and flow switches were connected via interface modules.
  - All tenant proprietary fire alarm panels were connected to the FA system via interface modules so that they could transmit alarm or trouble.
  - A floor warden station was installed on every floor to establish two-way telephone communication between each floor and the Fire Command Station. Also, a stairway standpipe fireline telephone jack was installed for the Fire Department's use.

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The 2001 Status of Completion of the new fire alarm system was as follows:

1. 1 WTC – 85% completed
2. 2 WTC –80% completed
3. 4 & 5 WTC - 60% completed
4. *Concourse Level - 100% completed*
5. Sub Grade Levels - 0% completed
6. Sub Grade Levels Backbone Modifications – 0% completed
7. XL3 Conversion to Pyrotronics MXLV system in all mechanical rooms 40% completed
8. Fiber Optic Loop - 0% completed

The fire alarm system was installed during the period 1995 to 2001 (its completion was in progress). It can be estimated that approximately 75% of the new Fire Alarm System was completed and its life expectancy was 50 years. The original fire alarm system, which would have been removed upon completion of the new fire alarm system, was still operational. Its life expectancy was 50 years. It can be estimated that 25% of the original fire alarm system, which was installed with the original building equipment was still in service.

2.12. Security System

A new security system was installed and finalized in year 2000. The system was comprised of electronic lobby turnstiles, digital imaging and badging, CCTV surveillance, door locking controls, subgrade assistance intercoms, intrusion detection systems, anti-ram barriers, enhanced security intercom systems, duress alarms and centralized monitoring through an Operations Control Center and an integrated computer system that enables all the components to interface.
The Integrated Security Program consists of the following 12 projects:

- Perimeter Security Barrier and Bollard System
- Access Control System
- Digital Imaging and Badging System
- Visitor Desk Station
- CCTV
- Door Locking and Control System
- Subgrade Assistance Intercoms
- Intrusion Detection/Alarm System
- Duress Alarms
- Emergency Electric Power Supply System
- Key and Lock Program
- Electronic Parking Access Control System (PACS)
- Glass Protection (Only implemented in parts of WTC 5)

In accordance with the Port Authority investigations it was determined that

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this was a first-of-its-kind integrated mega-high rise multi-tenanted security system. Other facilities with card access security systems, which were visited by the Port Authority, had few tenants and the central system did not communicate with the tenant system.

The security system was installed between 1996 and 2000. It consisted of 50% structures, 30% hardware and 20% software. For a system of this magnitude and complexity the life of the software is estimated to be 5 years. After that point the software needs to be upgraded or replaced. The life of the hardware is estimated to be 20 years, while the life of the structures is estimated to be 40 to 50 years.

2.13. Communications Systems

2.13. 1 Television Antenna

The antenna system consisted of the structural component and of the electronic component. The structural component was owned by the Port Authority and had a projected life of 40 years .It was installed in 1980. The electronic component was installed and operated by the networks. The antenna structure was upgraded in 1998 and its estimated life expectancy would have been 30 years.

2.13.2 800 MHz Radio System

The 800 MHz radio system was designed for police communications. The system was operational as of 1990. It is estimated that the life of the system would have been 15 years.

2.13.3 Telephone System

Diversity and redundancy for voice communications was achieved by providing both the Northern Telecom SL PBX (located in the WTC) and NYNEX. Dual sets of 56kbs circuits provided for continuous access to OA, IBM and the JSTC PATH police.
The 4000 pair telephone cable was installed and owned by the telephone company.
The system was operational as of 1990. It is estimated that the life of the system would have been 25 years.

2.13.4 Communication Dishes

Communication Dishes were installed on the roof of WTC 1, enabling tenants to access long distance communications channels.

2.14. Emergency Power Systems

The life safety emergency power system consisted of six (6) 1000kW,

480 V Wackesha diesel engine generator sets paralleled and located at the B6 Level. They were associated with a paralleling switchgear. The maximum life safety systems demand load was approximated to be 3.5MW.The diesel fuel storage consisted of one 10,000 gallon tank and one 5,000 gallon tank. It was estimated that this could provide approximately 30 hours of continuous operation of the life safety generator plant. The generators, which were originally water cooled were actually air cooled (change over implemented in 1995), had an estimated life expectancy of 40 years. They were installed with the original building equipment in 1970.

Tenants like Bank of America required additional emergency generation. In 1996 two (2) 1000 KVA generators were installed at level B2.

In addition to life safety emergency system, a tertiary source of power was provided in 1995. It consisted of a standby emergency feeder supplying a 2000 KVA transformer (480 volt secondary), which was available from the 27 KV PSE&G system supplying the PATH trains. This feeder was dedicated to supply such loads as the Fire Alarm System, Fireman's Service elevators, stairway lighting and the operations center. A distribution panel was provided for this purpose. The 2000 KVA transformer was always energized, however the secondary breaker was normally open. If the life safety generator plant failed to start, the secondary breaker was closed to energize the loads described above. It is estimated that the equipment for the tertiary source of power had a life expectancy of 40 years.

2.15. Standby Power Generation System

A new standby power generation system was installed in 2000 on the roof of World Trade Center 5 building to meet the tenants' critical standby power needs. The system consisted of four (4) 2200 kW/2750KVA Caterpillar engine sets generating at 13.8kV. The system was expandable to a total of six (6) sets or 13.2 Kw. The synchronizing switchgear was manufactured by ASCO. The bus was rated at 1200A and was capable of supporting the full six (6) generators. The distribution included a total of eight (8) circuit breakers. Two (2) circuit breakers supplied load banks, one fed Tower A, one Tower B, one fed Broadcaster and Cantor Fitzgerald at the 109th floor (not connected yet) and one fed an installation on the 41st floor dedicated to a tenant.
It is estimated that the standby power generation system would have had a life expectancy of 50 years, in view of the limited use of the equipment.

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3. Plumbing System

3.1 Description of the Domestic Water System

- Each Tower's domestic cold water system consisted of the vertical zones each fed by pumping stations as follows: 4 variable speed pumps, one cushion tank, 2 dual volume/dual reduction Clay Valve stations each located on B-1 Level, 41st Floor and 75th Floor MERs (the 7th floor MER contained the pressure reducing station only, no pumps) for a total of 12 pumps, 3 cushion tanks and 6 reducing stations in each Tower. Each Tower contained eight 2" risers to provide 4 cold water service lines to tenants (one in each quadrant) and 4 cold water service lines to the toilet facilities on each floor.

- The WTC Concourse and 4, 5 & 6 WTC were served by one zone of a pressurized domestic water system fed by 4 pumps and one cushion tank located in the B-1 Level under 5 WTC.

- The domestic hot water system paralleled the cold water system for the various zones described above. Water in each zone was heated by twin PK Steam Hot Water Heaters with re-circulating lines to maintain instant hot water.

3.2 Description of the Domestic Sanitary System

- Sanitary waste for the WTC were disposed via a dual pipe system: Separate storm leaders and building sanitary sewage waste.

- The storm leader provided storm water drainage for all roof areas, set backs and Plaza areas, all feeding into a 36" storm drain in the B-1 Level leading to further discharge to a Hudson River outfall. B-6 Level sumps and other sub-grade drain water were pumped into this storm drain. Storm leaders had horizontal offset at MERs to reduce velocity.

- Sanitary sewage waste lines, risers and vents paralleled the water lines at 8 locations on each Tower floor and various locations for concourse and Plaza buildings. Sanitary lines varies from 4" to 10" in size and emptied into the New York City 20" sewer lines with 10" feeds from the B-1 Level at six locations.

3.3 Description of the Fire Standpipe System

- Two main common closed loops served vertical FSP risers in the complex: A B-1 Level Loop serving all sub-grade areas, 1 & 2 WTC and a Concourse Loop serving the Concourse Areas and 4, 5 & 6 WTC. (Note:The B-1 FSP loop was completely replaced in 1995).

- FSP loops were fed by Siamese connections around the perimeter of the complex and by gravity feed fire reserve tanks for sub-grade areas, Plaza buildings, concourse and lower Tower floors.

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- Vertical FSP risers were located in all fire stairs in the WTC Complex including three in each Tower. Each stairwell FSP fed a Fire Hose Rack with a pressure reducing fitting as required and 150 feet of 1 ½" fire hose.

- Initial for primary feed to the FSP was by gravity feed fire reserve tanks located on the 20th, 41st, 75th and 110th Floors. Make-up for the fire reserve tanks was by domestic water feed.

- Secondary supply to FSP risers were by fire pumps discharging into the common loop in B-1 and the Concourse and common headers in the MERs serving the vertical FSP risers and located at the B-1 Level, Concourse and 7th, 41st, 75th and 108th Floor MERs. Each pump had a by-pass arrangement to enable a by-pass of a pump if not activated to "relay" water vertically. Each pump was supplied by alternate emergency power.

3.4 Description of the Sprinkler System

- The entire WTC complex was fully sprinklered. The Sprinkler System was installed in three basic phases. Phase 1: Sub-grade areas for the initial building construction; Phase 2: Sprinkler riser/main installation throughout 1 & 2 WTC including the sprinklerization of corridors, storage rooms, lobbies and certain tenant/PA spaces in 1976 in compliance with Local Law 5 to provide tenants with a compartmentalization or sprinkler fire protection option; Phase 3: The full sprinklerization of the entire complex for all remaining places from 1983 to the 2001(including 1993 blast recovery and ongoing up-grades/improvements/replacements).

- The Tower sprinkler systems were fed in the various zones from the gravity feed fire reserve tanks located on the 20th, 41st,75th and 110th Floors through a 4" vertical sprinkler riser located in the Janitor Closet on each floor of each building in the WTC complex.

- Each floor contained a sprinkler "rig" that included tamper switches, flow alarms, test connections, drainage valves, etc. as well as a sprinkler main down the center of each core corridor. This horizontal floor sprinkler main fed the tenant sprinklers zones, the corridor, core storage rooms, freight elevator lobbies, etc. All alarms were displayed in the Operations Control Center and mimic boards at Fire Command Stations.

- The sprinkler system in 4, 5 & 6 WTC and the sub-grade levels were served by an automatic pump pressurized system rather than gravity feed fire reserve tanks.

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4. Building Structural System

General Information:
Height: 1,368 and 1,362 feet (417 and 415 meters)
Owners: Port Authority of New York and New Jersey
Architect: Minoru Yamasaki, Emery Roth and Sons Consulting
Engineer: Leslie Robertson and John Skilling of Worthington, Skilling, Helle and Jackson
Ground Breaking: August 5, 1966
Opened: 1970-73; April 4, 1973 ribbon cutting

Architect Yamasaki and engineers Les Robertson and John Skilling collaborated closely forging a strong relationship between the towers' structural and architecture designs. Reaching these unprecedented heights (1,360+ feet), the structural engineers employed an innovative structural model: a rigid "hollow tube" of closely spaced steel columns with floor bar joist trusses extending across to a central core. This type of structure is sometime referred to as Veerendal truss, basically a hollow tube with multiple holes in it. The columns, finished with a silver-colored anodized aluminum alloy, were 18 3/4" wide and set only 22" apart.

Also, unique to the engineering design were its core and elevator system. The towers were the first mega-high rise buildings designed without any masonry in the core. Using a special drywall system fixed to the steel frame core solved concerns created by the possibility of intense air pressure from the buildings' high-speed elevators bursting cores. For the elevators to serve 110 stories with a traditional configuration would have required half the area of the lower stories to be used for shaftways. The Otis Elevators Company developed a unique express and local system. The system allowed passengers to ride large shuttle elevators, then change at "sky lobbies" on the 44th and 78th floors, thus halving the number of shaft-ways. The large shuttles, holding up to 55 passengers, were first-of-a-kind custom designed cars.

The structural system, derived from the I.B.M. Building in Seattle, was impressively straightforward. The 208-foot wide facade is, in effect, a prefabricated steel lattice, with columns on 39-inch centers, acting as wind bracing to resist all overturning forces; the central core takes only the gravity loads of the building. A light, economical and efficient structure results by keeping the wind bracing in the most efficient place, the outside surface of the building, thus not transferring the forces through the floor membrane to the core, as in most curtain-wall structures. Office spaces had no interior columns. In the upper floors there was close to 40,000 square feet of office space per floor. The two buildings had over 200 acres of floor space.

The floor construction was of prefabricated trussed steel, only 33 inches in depth, that spanned the full 60 feet to the core, and also acted as a diaphragm to stiffen the outside wall against lateral buckling forces from wind-load pressures. Special visco-elastic dampers connected the joists to structural wall system, damping the building's sway. Each tower comprised over 80 thousand tons of structural steel in the columns and truss frames.

The structural system included a perimeter of closely spaced columns, with an internal steel framed core. The floors were supported by a series of light trusses on pads (with visco-elastic dampers), which spanned between the outer columns and the lift core. The

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typical floor slabs were 1 1/2" deep ribbed metal decking with 4" composite reinforced structural concrete slab and embedded conduit. Lightweight concrete was used for typical floors and normal concrete for core areas. The slabs in mechanical equipment rooms and other special purpose areas were thicker, ranging from 6" to 8."

The foundation of the structure was comprised of a roughly 7.5 acre slurry wall enclosure six levels down to bedrock (the "Bath Tub"). The concrete slurry wall was consistently inspected – if a leaking crack was found, it was immediately grouted, and thus did not impair the structural integrity or shorten the long useful life of the slurry wall in any way. The towers structural column continued inside the enclosure down to the subgrade B-6 level where they were founded on a steel and concrete grillages tied into rock, whereas, buildings 4 and 5 were founded on concrete caissons to bedrock outside the closure. An expansion joint that isolates the towers from the plaza structure surrounds both towers. This expansion joint was replaced approximately eight years ago. Each Tower structure is founded on bedrock completely isolated from the plaza and parking level slabs. The Property Solutions Report commented the Austin J. Tobin Plaza paving is leaking into the Concourse level shops and common area. This statement is wholly inaccurate since the plaza waterproofing and paving waterproofing and paving were replaced in 2000.

The structural system was in excellent condition on September 11 having only used approximately 30 years of its probable useful life of several hundred years. The vertical loads of the building were predominant, thus there were no significant stress reversals to fatigue connections. Moreover, in areas of high overturning moment towards the base of the building in the subgrade, large direct-stress diagonal members were provided to bear these loads.

The building skin further protected the structural frame from corrosion. The aluminum alloy skin to the build was also in excellent condition. The Port Authority, consistent with the requirements of New York City Local Laws 10 & 11, visually inspected the skin and strengthened the connections to the frame and calking leaks when necessary. With this level of maintenance the skin also had an extremely long useful life.

DESCRIPTION OF PROGRAMS - PHASE II

Identify and briefly describe all building operational facilities, systems and structures improved since the construction of the World Trade Center. The systems include but are not limited to the following categories:

1. Common Area Improvement Program (Plaza, Concourse and Retail)

   To sustain the WTC, the Port Authority had to provide leadership to the Lower Manhattan area to help the financial district, and New York City in general, remain competitive as a global market place, while at the same time coping with the changes in the demand for office space in New York. The Port Authority undertook a major rehabilitation of the WTC Public Spaces (Concourse and Plaza) in the 1990's in the manner that helps to re-invigorate the downtown market as it did in the 1970s with the original WTC development.

   This redesign of the WTC public spaces was intended to maximize revenue while updating the facility to maintain the complex Class A rating. It is important to remember that these investments were made in then a volatile and difficult market.

   1.1 Strengthened viability of Concourse retail and public areas was accomplished by:

   - The Creation of a contemporary marketing ambiance by attracting new retail and food lessees and moving banks to the plaza level
   - Defining a hierarchy of public spaces, by creating new corridors and more efficient store aspect ratios
   - Clarifying functions, paths to functions, and defining user group paths, with new corridors and floor treatment
   - Integrating the space vertically and horizontally with surroundings by adding two new escalators, and
   - Clarifying all major junctures of circulation space or nodes with new corridors, new terrazzo and other floor/wall finishes.

   1.2 Enhanced and improved the Plaza as a grand public space by:

   - Preserving the majesty of the outdoor spaces
   - New plaza stone replacements
   - Providing public events and tourism amenities

   1.3 Dates: Start 1993 finish 2001

Cost of Common Area Improvement Program

PA JOB #	PROGRAM TITLE	ACTUAL $ SPENT THRU INCEPTION	COMMENTS
CW02-018	Public Space Code Improvements	$2,274,000	
CW02-035	Concourse Circulation Improvements	$20,794,000	
CW02-36	Public Space Infrastructure Improvement	$12, 030,000	
CW02-41	Tower Lobby Door Marble Replacement	$1,453,000	
CW02-42	Mall Circulation Improvements	$139,000	
CW02-61	Concourse Sprinkerlerization	$11,873,000	
CW02-65	Plaza Stone Replacement	$13,765,000	
CW02-72	Liberty Street Corridor	$2,954,000	
CW02-111	Priority Customer Service Improvements	$6,575,000	
TOTAL CONSTRUCTION COST	Common Area Improvement Program	$71,857,000*	* Not including Financial Expense & PA Overheads

2. **World Trade Center Recovery Program**

2.1 Structural

- Reconstruction of sub-grade floor slabs
- Replacement of floor beams and slab in the Liberty Room
- Replacement of Plaza beams and slab between Tower A and Greenhouse Restaurant.

2.2 Life Safety

- Replace and test sprinkler system in the blast area as needed
- Replace, recharge and test fire standpipe system in the blast area and towers as needed
- Repair Public Address system

- Replace Elevator Communications System: temporary relocation of Stentophone System; rewire control desk
- Clean and test Smoke Detection units
- Replace American Multiplex Fire Safety Monitoring System with Pyrotronics class A System including redundant computer systems for towers, dedicated risers, addressable devices, strobe warning lights, public address system and self diagnostics
- Retrofit existing emergency generator from domestic water cooled to air cooled - repair and expand distribution network, and build diking to keep emergency generate were at B6 in subgrade water free
- Install Battery Backup Emergency Light Fixtures at all stairwells, MERs, and elevator cabs and lobbies
- Install CCTV's Security System at the stair towers, building lobbies and truck dock
- Install Skylobby desks
- Install Cellular Phone System at Skylobby desks and tenant fire warden stations to decentralized communications

2.3 Dates: Start 1993 - Substantial Completion 2000

Cost of WTC Recovery Programs

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
	Structural	$34,800,000	Estimated
	Life Safety	$19,392,000	Estimated
	Mechanical	$64,325,000	Estimated
	Electrical	$24,900,000	Estimated
	Elevators	$3,269,000	Estimated
	Architectural	$15,000,000	Estimated
	General/Special Conditions	$28,000,000	Estimated
Total Construction Cost	*WTC Recovery Program*	*$189,686,000**	* Not including Removals, Financial Expense & PA Overheads

3 Mechanical Plant Expansion and Improvements (HVAC and Cooling)

3.1 New Chiller Plant

Supplemental Refrigeration Water Plant

The supplemental refrigeration plant had a capacity of 10,000 tons with five (5) 2,000-ton chillers. The chillers were custom-built for World Trade Center (limited height of the occupancy, 650 psi rating and ability to serve both high and low zones at this rating). The pipes from the supplemental plant were combined in a common header with the Base Building Refrigeration Plant.

The plant was provided with seven chilled water pumps and two booster pumps for river water re-circulation.

The supplemental plant was used to provide winter chilled water needs and provide 24/7 needs of tenants in certain portions of the Towers. It was much more economical to operate a 2000 ton machine than a 7000 ton machine, if the incremental requirement was relatively small (i.e.,1000 to 2000 ton).

The plant was supplied from a dedicated substation and transformers. This substation was supplied from two13.8 KV feeders originated in Power Distribution Center.

The plant became operational in 1996 and is estimated that it would have had a life expectancy of 50 years due to the excellent maintenance of the system, its designed level of redundancy and of the excellent maintenance, similar to the Base Building refrigeration Plant.

3.2 66" River Water Line

Condenser Water, River Water Pipes and Pumping Station

The original system consisted of 60" and 20" river water lines that were used to exchange waste heat with the Hudson River in lieu of cooling towers.

These lines ran to a pump house at river's edge through an easement with Battery Park City and served the original seven7000 ton refrigeration plant and one tenant computer cooling system. Due to the increased heat load, and as a result of the increased use of computers and other electrical equipment, a large supply of condenser water for cooling year round was required. In past years, before the heavy computer utilization, the cooling system would run on the 20" in the winter allowing for maintenance of the 60". When the 60" water line was required year round, allowing no time for its necessary maintenance, the new 66" river waterline was installed to satisfy the requirements of the system. At any given time only one set of pipes was used, and the other was in standby maintenance mode. Thus, two (2) sets of 60" and 66" pipes were essential to the operation of the chiller plants.

The new 66" line runs North of that location across West Street, and then South in front of the Financial Center to the Pump Station. The installation of the 66" line required demolition and reinstatement of Battery Park City hardscape. The new 66" pipe was steel, was supported on piles and was provided with sacrificing zinc anodes every 10 feet. This waterline was installed during the period 1995 to 1999. It is estimated that its life expectancy would have been 50 years.

The condenser water pump station was located along the river in an underground facility. Initially there were eight Johnson vertical turbine 12,000 GPM pumps and two Johnson vertical turbine 800 GPM pumps (emergency pumps). They were replaced in 1997 with eight (8) constant volume pumps. Four (4) pumps had a capacity of 18,000 gallons per minute (GPM) and the other four (4) pumps have a capacity of 13,000GPM. Two (2) pumps with capacity of 3,500 GPM each were emergency pumps. The river water plant operated at a temperature differential of 17°F. The pumps had remote start/stop capability.

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It is estimated that the pumps life expectancy would have been 30 years, due to the level of redundancy and the continuous maintenance of the equipment. Fresh water was used to lubricate the seals. There were two (2) 5,000-gallon fresh water tanks for storage. Two new HCL tanks used for water treatment were installed in 1998. Their life expectancy would have been 30 years.

Most of the pumping station and piping were outside the footprint of the WTC Complex.

3.3 Rehabilitation, Improvement and Upgrade of HVAC Systems

3.3.1 Upgrade of the condensed water piping for low high zones by adding 10" risers for tenant condensed water requirements

3.3.2 Upgrade of all fans for the Air Distribution System

3.3.3 Upgrade of the HVAC system in the third zone of the WTC 2

3.3.4 Various improvements and upgrades for the condensed water system

3.3.5 HVAC Control Modernization (hard wired start – stop system)

Cost of HVAC Capacity Upgrade Program

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
CW02-009	New Chiller Plant	$29,264,000	
CW02-006	66" River Water Line (Exterior)	$25,521,000	
CW02-073	66" River Water Line (Interior)	$8,206,000	
CW02-043	One World Trade, Third Zone HVAC Upgrade	$7,300,000	Approximately half for HVAC, balance for Electrical Upgrade
CW02-007	HVAC Distribution Rehabilitation	$17,357,000	
CW02-088	HVAC Control Modernization/Smoke Management	$1,356,000	
Total Construction Cost	HVAC Capacity Upgrade	*$89,004,000**	* Not including Financial Expense & PA Overheads

4. Electrical High Voltage Systems (13.8 KV Electric Service from Con Edison, 13.8 KV Power Distribution Center)

13.8 KV Electric Service

The 13.8 KV Electric service was originated from the Con Edison substation located at World Trade Center 7. It consisted of eight (8) feeders designed to support a capacity of 200 MVA, consistent with the requirements of a 10W/sq.ft distribution system operating under second contingency constraints. The feeders were sized at 2 x 1000 MCM Copper and supplied a Power Distribution Center (PDC) located in the Subgrade of the WTC Complex.

These new feeders were installed in year 2000 - 2001. The upgrade involved also the rehabilitation of the corroded slab, rerouting of new 5" conduits through this slab and pulling the new 2 x 1000 MCM cables from the Con Edison Substation to the Power Distribution Center.

The system life expectancy was 50 years, since the system, which was new, would have never operated at full load. Thus, its operating temperature would have been well below rated temperature and preserving the integrity of the insulation.

4.2 13.8 KV Power Distribution Center

The Power Distribution Center (PDC), was located in a fire rated switchgear room. It consisted of eight (8) 15 KV class Switchgears equipped with 48 vacuum circuit breakers (6 breakers per Switchgear – 1 main breaker and 5 distribution breakers). This Power Distribution Center supplied all the 13.8 KV feeders, which distributed power throughout the WTC Complex.

Forty one (41) original breakers were replaced in 1993 and seven (7) original breakers were replaced in 1998, with new 1200 Amp. 15 KV Class, draw-out vacuum breakers. Replacement of breakers also included their relaying protection.

The life expectancy of these breakers was 50 years. The breakers were maintained in accordance with a yearly program following the manufacturer's recommendations. Used parts were replaced as required on a regular basis. The relays were tested and exercised on a yearly basis.

5. 13.8 KV Distribution Feeders and Risers and Main Distribution Substations

5.1 13.8 KV Feeders, Distribution System

The Towers A and B were supplied from sixteen (16) feeders, 8 feeders per tower, routed vertically through 2 shafts per tower. Each shaft housed 4 feeders, which supplied the Switchgears and Transformers located in the Mechanical Equipment Rooms (MER) at 7th, 41st, 75th and 108th floors.

These feeders were sized 500 MCM copper up to the 41st floor MERs and 250 MCM aluminum between the 41st. floor and the 108 floor MERs. The feeders between the PDC and the 41st floor were replaced in 1993-1994.

The life expectancy of the new feeders described here above was 50 years.

5.2 Main Distribution Substations, 13.8/0.48 KV

- The New Main distribution substations were located on the, 41st, 75th of Tower 1 (two (2) per floor, or four substations) and 75th floor and 108th floor of Tower 2 (two (2) per floor or four substations).

- Two substations were located in the Mechanical Equipment Rooms (MERs), on each of these floors designated North and South substations. . Each was supplied by one of the 13.8 KV feeders. The substations located at the 75th and 108th floor served 16 floors, while the substations located at the 41st floor and 75th floor served 32 floors (16 up and 16 down).

- The new substations, which were installed on the 75th floor of each Tower and the 41st floor of Tower A became operational in 1996 and 1997. The new substations consisted of (4) 2000/2667/3325 KVA transformer with temperature rise ratings of 80/80/150°C with fan assisted cooling. These substations were arranged with network protectors connected to a common collector bus with normally closed circuit breakers that allow the bus to be isolated for maintenance purposes. The capacity of these substations was 6650 KVA under second contingency, thus, allowing for delivery of at least 10 W/sq.ft under these operating conditions. (see Substation Summary Table hereafter). These substations had a regular ground bus, connected to the building steel and an equipment ground bus. Ground faults were monitored within each compartment of the substation and isolated instantaneously, by tripping the adjacent breaker, or breakers. The substation was isolated from the ground, making each vertical section an independent grounding entity, protected by relays connected to the equipment ground bus. Incoming steel conduits were also isolated from the switchgear steel, to enable the operation of the ground fault protection downstream.

- On the 108th floor of Tower A, substations were installed in 1998, consisting of four (4) transformers arranged similar to the new substation described above. This substation was intended to supply tenant needs as well as elevators in the upper part of the Tower A.

  The 13.8 KV and 480 Volt electrical distribution systems were upgraded during the period 1990 to 2000 to support a power density of 10 W/sq.ft., as compared to the original design of the Complex, which provided for a power density of only 4 W/sq.ft. The WTC Complex peak demand was recorded to be 90 MW, during summer periods of high temperature and humidity. It was consistent with the 10 w/sq.ft required for the WTC Complex. It should be noted that the original design of the WTC Complex electrical systems couldn't have supported this load. The Substation Summary Table hereafter indicates the power densities under second contingency operation (see next Page).

Substation Summary Table

	Substation Vintage			Capacity	
Location	Tower A	Tower B	Floors Supplied	KVA in 2nd Contingency	W/sq. ft. 2nd Contingency
7th	Original (2)	Original (2)	8 – 24	6,000 for each tower A and B	11.7
41th	New (2)	Original (2)	25 – 57	Twr. A: 13,300 Twr. B: 6000 up 13,300 down	12.9 11.7 up 17.5 down Dean Witter
75th	New (2)	New (2)	58 – 92	13300 each tower A and B	12.9
108th	Original (1) & New (1)	Original (2)	93 – 108	Twr. A: 6000 +13300 Twr. B: 6000	17.5 11.7

*Available under second contingency.

The substations operated at a load well below their full capacity, since they were designed for second contingency operation. Thus, their life expectancy was 50 years, whether the "original" or the "new". The original substations were installed with the original building equipment in 1970. The new substations were installed as follows:

- 1989 (Dean Witter – 1 substation). It is not included in the present Capital program
- 1996 – 1997 (41st and 75th floor Tower A and B – 6 Substations)
- 1998 (108th floor Tower B 1 - Substation)
  In addition the Port Authority was conducting an intense maintenance program on all substations and also monitoring the eventual degradation of the insulation, with power factor tests performed every three years. The latest power factor tests on the original substations and transformers showed an insignificant degradation of the insulation. The latest power

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factor tests on the new substations showed no degradation of the insulation, which confirms that the life of the substations exceeds the industry average life expectancy.

6. **480 Volt Vertical Distribution System (Bus Duct)**

The original vertical distribution in the Towers consisted of 4000 Amp. FPE bus ducts, which were distributing power to the tenant floors at 480/277 Volt. A fused plug in disconnect switch, rated 200 Amp or 400 Amp was provided in each electrical closet at each floor.

There were two 4000 Amp risers in each Tower and two electrical closets on each floor. Each electrical closet was supplied from one of the risers.

To increase the capacity of the existing bus duct, to match the capacity of the new substations at a power density of 10 W/sq.ft and add flexibility for tenants located at the upper zone served by new substations, new 4000 Amp bus duct risers were added in 1998.

In both Tower A and B, four (4) bus ducts rated 4000 Amp were added for all 32 floors served by the new substations located at the 41st floor and at the 75th floor (16 floors up and 16 floors down). The tenants located at the first 8 floors were connected to the existing bus, while the tenants located at the next floors were connected to the new bus duct, via new fused plug-in disconnect switches.

The life expectancy of the bus duct, "original" or "new" was 50 years, since its 4000 Amp nominal rating was well below its operating current. The new bus duct was installed between 1996 and 1998. The original bus duct was installed with the original building equipment in 1970.

See the next page for a table showing these and other recent upgrades under the Electric System Upgrade program:

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Cost of Electrical System Upgrades

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
	13.8 KV Electric Service from Con Edison	$10,000,000	Estimated
CW02-002	13.8 KV Feeders and Substations at 41st and 75th floors Towers A and B	$49,225,000	
CW02-003	13.8 KV Power Distribution Center (PDC)	$10,085,000	
CW02-043	One World Trade Center, Substation at 108th Floor	$7,297,000	Approximately h for Electrical Upgrades balanc for HVAC Upgrades
CW02-004	480 Volt Vertical Distribution System (Bus Duct)	$7,838,000	
CW02-093	Misc. Electrical System Upgrades	$2,518,000	
Total Construction Cost	*Electrical System Upgrades*	*$86,963,000**	* Not including Financial Expens & PA Overheads

7. Upgraded Emergency Power Systems (Tertiary Source of Power, Emergency Lighting For Staircases, New Exit Sign System)

7.1 Tertiary Source of Power

In addition to the secondary sources of emergency power, a tertiary source of power was provided in 1995.
It consisted of a standby emergency feeder supplying a 2000KVA transformer (480 volt secondary), which was available from the 27 KV PSE&G system supplying the PATH trains. This feeder was dedicated to supply such loads as the Fire Alarm System, Fireman's Service elevators, stairway lighting and the operations center. A distribution panel was provided for this purpose. The 2000KVA transformer was always energized; however the secondary breaker was normally open. If the life safety generator plant failed to start, the secondary breaker was closed to energize the loads described above. It is estimated that the equipment for the tertiary source of power would have had a life expectancy of 40 years.

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7.2 Emergency Lighting for Staircases and Elevators

The emergency Lighting System was upgraded in 1993, subsequent to the 1993 bombing, by providing 2500 fixtures with battery packs in the staircases. In addition all elevators were provided with emergency lighting, also backed up by a battery pack. There was a total of 244 elevators, or 244 elevator emergency fixtures for the entire WTC Complex. We estimate that the construction cost per emergency fixture installed was approximately $400.

7.3 Emergency Lighting System and Exit Sign System

The initial exit sign system illuminated with fluorescent lamps was replaced with modern LED illuminated exit signs with a consumption of 1.5 W per sign. This represented a reduction of about 14 W per sign. The program, which replaced about 5000 exit signs during the period 1997 to 2000, was implemented for the entire WTC Complex. The life expectancies of the fixtures and exit signs were 20 years. The life expectancy of the battery packs was 10 years. Therefore it would have been expected to replace the battery packs once over the life of the lighting fixture. This program was implemented in conjunction with New York Power Authority (NYPA) and was funded by NYPA. The Utility would recover the investment, progressively from savings.

8. Standby Power Generation System

A new standby power generation system was installed in year 2000 on the roof of World Trade Center 5 building to meet the tenants critical standby power needs. The system consisted of four (4) 2200 kW/2750KVA Caterpillar engine sets generating at 13.8kV. The system was expandable to a total of six (6) sets or 13.2 KW. The synchronizing switchgear is manufactured by ASCO. The bus was rated at 1200A and was capable of supporting the full six (6) generators. The distribution included a total of eight (8) circuit breakers. Two (2) circuit breakers supply load banks, one fed Tower A, one Tower B, one fed Broadcaster and Cantor Fitzgerald at the 109th floor (not connected yet) and one fed an installation on the 41st floor dedicated to a tenant.

It is estimated that the standby power generation system would have had a life expectancy of 50 years, in view of the limited use of the equipment.

9. Lighting System

The original lighting system consisting of lighting fixtures equipped with four (4) 40 watt fluorescent lamps and electromagnetic ballasts, was progressively replaced with fixtures equipped with either 2-T8 32 W lamps and electronic ballasts, or 2 lamps biax and electronic ballast.

Approximately 90% of the initial fixtures were replaced during the period 1990 to 2001. The power density of the lighting was reduced from 4 W/sq.ft to 1.5 W/sq.ft., for a total reduction of about 8 MW for the entire WTC Complex. On the average, on each floor, there were 600 fixtures 2' x 2', for a total of about 150,000 for the entire complex, including the subgrade and WTC 4 and WTC 5. The life expectancy of the lighting fixtures was 20 years.

Cost of Emergency Power Upgrades

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
CW02-044	Substation Ground Fault Protection	$3,206,000	
CW02-049	Tertiary Source of Power (PSE&G)	$2,044,000	
	Emergency Lighting for Staircases and Elevators	$1,100,000	Estimated
	Exit Sign System	$2,000,000	Estimated
CW02-086	Tenant Stand-by Power (Generator System)	$26,775,000	
	Lighting System	$6,750,000	Estimated
Total Construction Cost	Emergency Power Upgrades	*$41,875,000**	* Not including Financial Expense & PA Overheads

10 Police Command Center

10.1 Description of the Program

After the Police Command Center (PCC) was destroyed in 1993, the Port Authority implemented a program to replace the original center and consolidate PA police operations in one centralized space. Eventually PCC was installed on the Plaza Level of 5 WTC and was in full operation well before 9/11/01. The PCC occupied approximately 6,000 square feet and construction was complete in 1998. Essentially the PCC is the equivalent of a full-service police precinct station located in New York City.

10.2 Scope of PCC Facility

- Police Desk, Reception and Public Assistance Area: All central computer-assisted receiving and dispatching operations, communication consoles, officer radio operations, CCT surveillance of holding cells, etc.

- Prisoner Holding Cell facilities: Prisoner/arrest processing area, two holding cells, CCTV surveillance, etc.
- Reserve Room/Administration: Multi-purpose office waiting/mustering/eating area, management and supervisory area, administrative support, equipment storage, etc.
- Detective Area: Interview rooms, line up room, detective work area, holding area, etc.
- *Police Locker Rooms: Male/female supervisors' and separate male/female* officers' locker rooms including shower and toilet facilities

10.3 Dates: Start 1998 – Substantial Completion 2000

Cost of Police Command Center

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
	Police Command Center	**$7,000,000**	**Estimated**
TOTAL CONSTRUCTION COST	**Police Command Center**	***$7,000,000****	***** Not including Financial Expense & PA Overheads**

11. Fire Alarm System

11.1 Existing System

11.1.1 The existing fire alarm (FA) system as manufactured by American Multiplex System, covered the following areas:
- a. One World Trade Center (Tower One).
- b. Two World Trade Center (Tower Two).
- c. Four World Trade Center.
- d. Five World Trade Center.
- e. Concourse Level.
- f. Sub Grade Levels.

11.1.2 The existing centralized FA system, consisted of Remote Multiplexing Terminals (RMT's) to which the existing FA devices (*smoke detectors, manual pull stations, tamper and flow switches,* etc.), tenant panels, and security sensors were connected. The RMT's were linked to the old Operation Control Center (OCC) main and back-up computers.

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11.1.3 Each of the mechanical rooms in 1 & 2 WTC were connected to a Pyrotronics XL3 system and linked to a Pyrotronics CXL panel in the OCC.

11.1.4 An Executone System located in the OCC, supplied the public address communication system between the corridor ceiling mounted speakers, the HVAC duct mounted speakers, the stairway speakers, and the OCC. In addition, Break Glass Stations, located on each floor, were wired back to the Executone System and used to notify the Fire Department of an alarm.

11.2 Fire Alarm Phases

In order to maintain the existing FA system while installing the new system, a three-phase plan was developed as follows:

11.2.1 Phase I – Installation of the new Pyrotronics MXLV backbone riser equipment, which consists of remote transponder panels (MXLRV) and amplifier cabinets placed (typically) every third floor in each of the Towers.

A Terminal Strip Cabinet (TSC) which consists of terminal blocks, was placed on every floor and wired back to the transponder so any existing or new devices such as smoke detectors, speakers etc., would have been connected to the new system under Phase III.

An Interface Cabinet (IC), which consists of interface modules, was placed in the corridor electrical closet next to the existing RMT in order to interface with the existing FA system.

11.2.2 Phase II – The connection between the new FA system to the existing system is accomplished under this phase and was performed on a point-by-point basis. During this phase, both the new Pyrotronics and the existing American Multiplex System were operating concurrently. Once the transfer was completed, the existing system was no longer a part of the fire alarm system, and all functions were carried out by the Pyrotronics MXLV system.

11.2.3 Phase III – This phase was to bring all occupied areas to full conformance with the New York City Building Code – Class "E" system, the ADA, the NFPA, and all other applicable codes. New addressable area and duct smoke detectors, pull stations, strobes, speakers, and warden's phones were installed and wired to the TSC's, which were installed under Phase I.

11.3 New Fire Alarm System Capabilities

The new decentralized system includes six independent FA systems as follows:

11.3.1 1 WTC, 2 WTC, 4 WTC, 5 WTC, Concourse Level, and Sub Grade Levels. Each of the six systems is linked to a Network Command Center (NCC), located in the Fire Command Station (FCS) at the lobby of each of the four buildings. In addition, remote NCC's were installed in buildings 4 & 5 to back-up each other, Sub Grade and Concourse main and remote NCC's in buildings 1 & 2 respectively, and 2 WTC remote NCC in 1 WTC. Furthermore, back-up NCC's for all six systems were installed in the new OCC, so if there is an emergency, the entire WTC FA system can be monitored and controlled from a safe remote location.

11.3.2 Each of the NCC's is connected to a dedicated logging printer providing a sequential log of events and operator actions. Additionally, a color graphics software is installed in the new FA system so that in the future, when the design of the FA system is completed and floor plans (for the entire WTC complex) indicating the location of all FA devices were available, a color laser printer can be used to print graphic screen images, which in the event of an alarm, could view a floor plan with the exact location of the active device so that the response team can locate the problem area easily and act accordingly.

11.3.3 To enhance the integrity and reliability of the new FA system, a Style 7 Network wiring scheme was chosen, which includes two additional independent network risers installed in two additional rigid conduits (totaling three conduits), at different locations (fire alarm closet, and two separate stairways). This scheme of wiring accommodated any type of circuit malfunction (short or open) in any section of the network risers. Additionally, the network risers utilize #14 AWG Teflon cables (twisted pair, 600V, 200°C).

11.3.4 Furthermore, the Pyrotronics NCC Global/Local (NCC-G/L) Fiber Optic Token Ring LAN, which operates independently of both MXLV network and the RS-485 style 7 network, allows each NCC on the LAN to monitor/control any combination of the six FA systems. The Fiber Optic cable was installed in rigid conduits and was be run in a closed ring topology around the entire WTC complex. The be provided with self healing characteristics in the event of damage of the Fiber Optic assembly.

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11.4 Phase III Implementation

The following systems/devices were used to bring all occupied areas up to full conformance with all applicable codes:

11.4.1 Wall-mounted strobe units were installed in all corridors, bathrooms, common areas, and all occupied tenant spaces.

11.4.2 Ceiling-mounted speakers were installed in all corridors, bathrooms, common areas, and all occupied tenant spaces.

11.4.3 Addressable area smoke detectors were installed in all base-building electrical and telephone closets, mechanical rooms, elevator machine rooms, and in elevator lobbies for elevator recall. Additionally, duct mounted smoke detectors and area detectors installed in front of the return/supply air grills were installed for fan shut-down.

11.4.4 Pull stations were installed next to each stairway and in the main exits in the main lobbies.

11.4.5 All existing sprinklers tamper and flow switches were connected via interface modules.

11.4.6 All tenant proprietary fire alarm panels were connected to the FA system via interface modules so that they can transmit alarm or trouble.

11.4.7 A floor warden station is installed on every floor to establish two way telephone communication between each floor and the Fire Command Station. Also, a stairway standpipe fireline telephone jack is installed for the Fire Department use.

11.5 Summary

The construction of Phases I and II of the fire alarm system in all areas is completed. The status of Phase III contracts and the balance of the construction costs were as follows:

11.5.1 1 WTC – Phase III was about 85% completed and a balance of $2,400,000 for completion.

11.5.2 2 WTC – Phase III was about 80% completed and a balance of $2,800,000 for completion.

11.5.3 4 & 5 WTC - Phase III was about 60% completed and a balance of $2,400,000 for completion.

11.5 4 Concourse Level - Phase III was 100% completed.

11.5.5 Sub Grade Levels - Phase III was 0% completed and a balance of $10,600,000 for completion.

11.5.6 Sub Grade Levels Backbone Modifications – 0% completed and a balance of $2,800,000 for completion.

11.5.7 XL3 Conversion to Pyrotronics MXLV system in all mechanical rooms – about 40% completed and a balance of $1,400,000 for completion.

11.5.8 Fiber Optic Loop - 0% completed and a balance of $3,000,000 for completion.

It is estimated that the life expectancy of the system would have been 25 years.

Cost of Fire Alarm System

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
CW02-033	**Fire Alarm Systems Phase I & II**	**$25,647,000**	
CW02-034	**Fire Alarm Systems Phase III**	**$43,220,000**	
CW02-078	**Fire Alarm Systems Phase III - Tenant**	**$183,000**	
Total Construction Cost	**Fire Alarm Systems**	***$69,050,000***	***Not including Financial Expense & PA Overheads**

12. Miscellaneous Life Safety Improvements and Sprinklerization Program

12.1 Description of the Program

The initial base building provided for Fire Standpipe (FSP) protection in the Towers and Plaza Buildings and no sprinkler system installation (except in the sub-grade Levels). In response to the enactment of Local Law 5 and other NYC Building Code Local Law enactments related to the fire protection of high rise office towers built after 1973 the Port Authority voluntarily retrofitted the WTC complex to comply with the new NYC Building Code Requirements supplemented by PA imposed life safety requirements unique to the WTC. These requirements provided tenants the option of achieving fire protection compliance by a compartmentalization or a sprinklerization option. The Scope of miscellaneous life safety and sprinkler system upgrades/improvements, other than certain fire alarm, concourse circulation and blast recovery improvements discussed elsewhere, is outlined below.

12.2 Scope of Fire Life Safety Improvements

Architectural Modifications - On all floors:

- Upgraded core wall construction to provide for a 2 hour rated fire separation from one side of a tower floor to the opposite side (Where core wall were already 2 hour rated, such as in elevator shafts, upgrades where not previously required).

- *Installed a double acting set of rated HM fire doors in the core corridors where* the above 2 hour rated fire separation crossed the corridor (This enabled one half of a typical tower floor to serve as a horizontal fire refuge for the other.) Doors included special magnetic hold open hardware and closures linked to smoke detectors in floor return air ducts.

- Restored all ceilings in corridors and lobbies affected by fire protection installations.

- Provided slab-to-slab 1hour fire rated walls to enable a maximum of 10,000 gross square foot compartmentalization on each side of the 2 hour rated fire separations.

Sprinkler System Installation

- The entire WTC complex was fully sprinklered. The Sprinkler System was installed in three basic phases. Phase 1: Sub-grade areas for the initial building construction; Phase 2: Sprinkler riser/main installation throughout 1 & 2 WTC including the sprinklerization of corridors, storage rooms, lobbies and certain tenant/PA spaces in 1976 in compliance with Local Law 5 to provide tenants with a compartmentation or sprinkler fire protection option; Phase 3: The full sprinklerization of the entire complex for all remaining places from 1983 to the 2001(including 1993 blast recovery and ongoing up-grades/improvements and replacements).

- The Tower sprinkler systems were fed in the various zones from the gravity feed fire reserve tanks located on the 20th, 41st,75th and 110th Floors through a 4" vertical sprinkler riser located in the Janitor Closet on each floor of each building in the WTC complex.

- Each floor contained a sprinkler "rig" that included a tamper switches, flow alarms, test connections, drainage valves, etc. as well as a sprinkler main down the center of each core corridor. This horizontal floor sprinkler main the fed tenant sprinklers zones, the corridor, core storage rooms, freight elevator lobbies, etc. All alarms were displayed in the Operations Control Center and mimic boards at Fire Command Stations.

- The sprinkler system in 4, 5 & 6 WTC and the sub-grade levels were served by an automatic pump pressurized system rather than gravity feed fire reserve tanks.

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HVAC Modifications On all floors:

- Installed fire dampers in all ducts that penetrate any rated compartmentalization or fire separation walls.
- Installed fire shutters/dampers over all door louvers in core corridors.

Electrical Modifications

- Provided for electronic door closing of double acting magnetically held open doors in corridors.
- Retrofitted all elevators to enable automatic return to lowest lobby floors of all elevators.
- Installed smoke detectors in all elevator lobby areas throughout the complex to activate elevator return and magnetic door hold open release.
- Provided alarm systems hard wired to the Operations Control Center for tamper switches, sprinkler flow alarms, smoke detectors, thermostatic alarms, door closing alarms, etc. along with all related alarm system control boards, display panels and command stations.
- Installed an every floor in the complex Floor Fire Warden Stations linked to the Operations Control Center and new Fire Command Stations in the lobbies of all building in the Complex.
- Installed a storage battery supply and UPS system for the above alarm and supervisory systems.

12.3 Dates: Start 1975 – Substantial Completion 2001.

Cost of Sprinkler System & Miscellaneous Life Safety Upgrades

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
	Local Law 5 & 16 Upgrades	$20,000,000	Estimated
CW02-078	Life Safety Upgrades	$5,672,000	
	Fully Sprinklerized Complex	$40,000,000	Estimated
CW02-082	Other Sprinkerization Work	$2,438,000	
Total Construction Cost	Sprinkler System & Miscellaneous Life Safety Upgrades	*$68,110,000**	Not including Financial Expense & PA Overheads

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13. ADA Compliance Program and Upgrades

13.1 Description of the ADA Program

Throughout the WTC complex modifications were made in public areas to accommodate the handicapped in conformance with ADA requirements.

13.2 Scope of ADA Upgrades

- Install three sets of automatic sliding doors in each Tower Main Lobby (2 in the "pressure lock vestibules and one onto the Concourse).
- Install automatic sliding doors in all other vestibules leading to the street.
- Install new elevator and shaft from the PATH Level to the WTC Main concourse level.
- Install sloped ramps from the WTC concourse to street level in conformance with ADA requirements.
- Upgrade toilet facilities throughout the WTC complex to meet ADA requirements.

13.3 Dates: Start 1997 – Substantial Completion 2000

Cost of ADA Program & Upgrades

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
CW02-021	ADA Projects	$4,826,000	
CW02-087	Multi-Tenant Floor Restroom Upgrades	$6,812,000	
Total Construction Cost	ADA Program & Upgrades	*$11,638,000**	* Not includi Financial Expense & P. Overheads

14. Subgrade Rehabilitation Program and Upgrades

14.1 Description of the Program

After the WTC Sub-grade PA Operations Areas were destroyed in 1993, the Port Authority implemented a program to replace, upgrade and consolidate the sub-grade building operations and maintenance facilities for the WTC Department's Plant and Structures Division in accordance with a WTC Sub-grade Redevelopment Master Plan.

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14.2 Scope of Sub-grade Improvements

- Sub-grade Plant and Structures facilities occupied approximately 210,000 square feet and was planned to accommodate up to 700 staff distributed over six sub-grade levels: B-1 through B-6.
- Provide for the complete space requirements of the following Plant and Structures Division units:
  - Cleaning
  - Structural
  - Carpenters
  - Mechanical
  - Electrical
  - Elevators/Escalators
  - Painters
  - Locksmiths
- Provide all necessary toilets, showers, locker rooms, lunch facilities, storage, stock rooms, administrative areas, management offices, etc. for the above units.
- Provide for the following Plant and Structures Shops, complete with all necessary tools, specialized equipment and associated environmental controls (special exhaust and ventilation requirements):
  - Structural Woodworking Shop
  - Structural Laminating/Paint Shop
  - Structural Welding Shop
  - Mechanical Welding Shop
  - Hazardous Waste Area (near Truck Dock)
  - Elevators/Escalator Repair Shop
  - Locksmith Shop
  - Plumbing/Sprinkler Shop
  - Mechanical HVAC Shop
  - Radio/Communications Repair Shop
- Rehabilitate the sub-grade structural slabs damaged in 2/93
- Provide for sub-grade building code upgrades

14.3 Dates: Start 1995 – Substantial Completion 1997

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Cost of Subgrade Redevelopment

PA JOB #	SYSTEM/ELEMENTS	ACTUAL $ SPENT THRU INCEPTION	COMMENTS
	Subgrade Redevelopment	$20,000,000	Estimated
CW02-046	Subgrade Slab Rehabilitation Phase I	$24,910,000	
CW02-076	Subgrade Code Upgrade Project	$2,504,000	
CW02-097	Subgrade Slab Rehabilitation Phase Ii	$7,030,000	
Total Construction Cost	Subgrade Redevelopment	$54,444,000	* Not including Financial Expense & PA Overheads

15. Windows Commercial Space

This project involved food storage, receiving and bulk handling area for the Windows of the World Restaurant. The construction cost which does not include Financial Expenses & PA Overhead was $2,300,000.

16. Elevator/Escalator Modernization Program

This project was required to enhance the highly competitive position and marketability of office space in World Trade Center. It provided significant enhancement to the level of performance, reliability and maintainability of the elevators in One and Two World Trade Center and plaza building four and five by modernizing communication system, guiderails, cab interior finishes and other operating components the elevator control equipment, and cab interiors.

The World Trade Center elevator and escalator system contained 244 local, shuttle and freight elevators and 73 escalators and support equipment in One, Two, Four and Five World Trade Center, including the Concourse and subgrade levels. There were greater demands than ever being placed on the World Trade Center's major building systems, including its elevator and escalator system. There were more multi-floor tenants and a greater density of workers on each floor than when the facility first opened.

Approximately 400,000 passengers used the system each day, and a decline in the level of service would have been quickly noticed. The shuttles were the largest building elevator cab and were custom manufactured for the Trade Center. Much of this equipment, before recent complete modernization, had been operational for more than 20 years and represented technology that is more than 25 years old. The World Trade Center elevators and escalators were manufactured and installed by Otis Elevator

Company, the initial contract for which was approved by the Port Authority Board in October 1966. The maintenance contract for the equipment was also awarded to Otis at the same time. The maintenance contract still remains in effect until October 1993. At that time a new maintenance contract was awarded to ACE Elevator Inc.

16.1 Elevator Cab Replacement Program (Marble Cabs)

In the past few years, staff identified major components of the vertical transportation system, which required rehabilitation, upgrading or replacement, cab interior finishes, and other operating components. A number of these projects, including new cab interior, finishes, a new communication system, new position indicators, anti-contact door openers and general rehabilitation work. The cab interior finishes includes marble on honeycomb aluminum backing with chromed stainless grab bars and newly carpeted floors. The shuttle cabs were all marble wall and a stainless ceiling; the locals were enamel walls with marble trim.

16.2 Elevator Control Modernization

Thorough maintenance was kept and would have continued to keep the system functional for the foreseeable future, the obsolescence of controls equipment created the need for a new solid-state controls system, although in August 1992, a team of outside elevator experts unanimously agree that the World Trade Center had "the highest level of elevator service of all mega-high rise building that the had experienced over their career.

Industry research indicated waiting time of 20-30 seconds as the maximum amount of time a passenger will wait before becoming impatient. Although waiting times varied throughout the World Trade Center, depending upon the service loads and demands of each elevator bank most met these guidelines. The new dispatching equipment significantly improved waiting times, primarily by increasing elevator group efficiency.

The earlier dispatching equipment employs outdated relay and transistor logic, and operates by assigning each elevator in an elevator bank to a service zone (typically two floors or the lobby). When a hail call was registered, the dispatching system assigned it to the corresponding zone elevator. If that elevator was unavailable, the system did not dispatch another elevator. Rather, it would wait for an elevator to pass through the zone to answer the call. Only if there was an exceptionally lengthy delay (60-90 seconds) would the dispatching system assign the call to another elevator.

In contrast, the new elevator dispatching systems provided for an estimated time of arrival (ETA) strategy, which analyzed all elevators in a group with respect to their location and other car calls and stops. The elevator with the shortest ETA (which is not necessarily the nearest car in terms of distance) was then assigned to newly registered hall calls. These dispatching assignments were continuously updated, as the system constantly recalculates ETA's and reassigned elevators as appropriate.

The installed modern elevator dispatching equipment could also facilitate custom programming for specific tenant operating needs (e.g. locking out certain floors). Equipment based on modular microprocessor boards was easier to upgrade as new technologies are developed and installed. Future features would have included card access, and advanced intelligence, which would recognize typical traffic patterns (e.g

morning up-peaks, afternoon down-peaks) and optimize elevator group performance through elevator channeling or other sophisticated dispatching methods. Prototype infrared sensors are also being developed which can count the number of people waiting at each floor and determine whether more than one car is needed to handle the call.

Cost of Elevator/Escalator Modernization Program

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENT*
CW02-010	Elevator Cab Interiors	$7,948,000	
CW02-012	Plaza Building Elevator Control Modernization	$5,900,000	
CW02-014	Tower 1 Elevator Control Modernization	$18,131,000	
CW02-069	Tower 2 Elevator Control Modernization	$14,536,000	
CW02-068	Shuttle Shaft Improvements	$8,309,000	
CW02-092	Mechanical/Elevator system Upgrades	$10,243,000	
Total Construction Cost	Elevator/Escalator Modernization	*$65,067,000	* Not including Financial Expense & PA Overheads

17. Permanent Security Program

The World Trade Center Security Program provided security capabilities for the World Trade Center. As the World Trade Center was one of the world's most visible buildings, the Port Authority, as owner, was prudent in heightening its ability to protect the buildings occupants and visitors.

The mission of the Security Program was to take reasonable and prudent action to enhance the overall security of the World Trade Center to minimize the threat of a terrorist action and to control unauthorized access (entry). The key word was "minimize" the total elimination of threat was virtually is impossible.

System Description

The system was comprised of electronic lobby turnstiles, digital imaging and badging, CCTV surveillance, door locking controls, subgrade assistance intercoms, intrusion detection systems, anti-ram barriers, enhanced security intercom systems, duress alarms and centralized monitoring through an Operations Control Center and an integrated

computer system that enables all the components to interface. The parking access control portion was advanced through a separate program. While the perimeter protection portion of the program was installed with the Common Area Improvement Program.

The Integrated Security Program consists of the following 12 projects:

17.1 Perimeter Security Barrier and Bollard System
17.2 Access Control System
17.3 *Digital Imaging and Badging System*
17.4 Visitor Desk Station
17.5 CCTV
17.6 *Door Locking and Control System*
17.7 Subgrade Assistance intercoms
17.8 Intrusion Detection/Alarm System
17.9 *Duress Alarms*
17.10 Emergency Electric Power Supply System
17.11 Key and Lock Program
17.12 Electronic Parking Access Control System(PACS)
17.13 Glass Protection (**Only implemented in parts of building five .)

Program components were defined in the following manner:

17.1 Perimeter Security Barrier & Bollard System

- Provided a hydraulic anti-ram barrier and a bollard vehicle barrier system
- Embedded anti-ram barriers were hydraulic and electro-mechanical
- All-weather card readers were installed on driver accessible stands interior and exterior to each anti-ram barrier. These were included in the integrated security intercommunications stations.
- Provided "imbedded, closing vehicle detection loops" to automatically raise barriers once they have been lowered to allow a vehicle to pass, unless the barriers have been set to "manual operation" by the security guard.
- Anti-ram barriers were to be provided at all vehicle and truck entry points
- Retractable anti-ram barriers were installed at the following locations:
  - (1) Church St.at Vesey St. (Market entrance)
  - (2) Church St. at Dey St. (Plaza emergency entrance)
  - (3) Liberty St. at Greenwich St. (emergency entrance)
  - (4) Liberty St. (ramp H)
  - (5) West St. (ramp A)
  - (6) West St. (ramp B)
  - (7) West St. (ramp C)
  - (8) West St. (ramp D)
  - (9) Vista Hotel, West St. *garage entrance ramp*
  - (10) Vista Hotel, West St. garage exit ramp
  - (11) Barclay St. (ramps E&F)
  - (12) Barclay St. (ramp G)

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The bollard vehicle barrier system consisted of static and hydraulic bollards designed to prevent vehicle access along plaza and street levels. Retractable and static bollards and planters were installed at building WTC 1 entry points, at building WTC 3 entry points, at Church St./Plaza entry points and at other points that the PA directed. The security stations remotely controlled hydraulic anti-ram barriers and hydraulic bollards. Concrete planters as barriers (including necessary drainage from planters and substantial upgrades) were designed to meet "weight loading" limits based on structural studies that were conducted by the contractor. After this work the curb and sidewalk were restoration.

17.2 Access Control System

The access control system controlled access to elevators, the subgrade, the pump statior and other critical doors in the building. Equipment included electronic access cards, electro-mechanical locking devices, bi-directional turnstiles and proximity card sensor system. All building lobbies (WTC 1,2,4,5) and entrances to the J and K subgrade parking lot elevators were equipped with turnstiles. All tenants, long-term visitors and contractors were issued electronic access cards with access granted on an "entry need" basis.

17.3 Digital Imaging and Badging System

Video imaging and badging equipment recorded and store video images and data on tenants, long-term visitors and contractors.

17.4 Visitor Desk Stations

Single and multi-day passes were issued to visitors to give them access into secured areas of the complex. Individual visitor data was be recorded and stored in the security system's database. Visitor Desks were position in both towers and the plaza buildings.

17.5 CCTV

The CCTV System was an event-activated system and alerted staff and record activity at sensitive access points around the complex both indoors and outdoors.
Equipment included CCTV cameras, fiber optic cable networking and monitoring equipme located in the Permanent Operations Control Center (POCC).

17.6 Door Locking and Control System

The door locking and control system electronically locked and unlocked all transitional doors between secured and unsecured areas of the complex. The system operated both remotely and manually and met all Fire Department code requirements.

17.7 Subgrade Assistance Intercoms

Subgrade assistance intercoms connected persons in the subgrade directly with the POCC.

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17.8 Intrusion Detection/Alarm System
Intrusion detection sensors were installed in a variety of locations. They were installed on doors, primary mechanical equipment rooms, turnstiles, subgrade fan/ventilation openings and in Plaza service hatches. All sensors were wired to the POCC where they alerted staff if an intrusion occurs.

17.9 Duress Alarms
Duress alarms were installed in the subgrade, elevator lobbies, mechanical equipment rooms and guard booths. They were connected to the POCC (Permanent Operations Control Center), Police Command Center (PCC), and the fire command station in Buildings 1,2,4,5, the Vista Hotel and US Customs House.

17.10 Emergency Electrical Power Supply Systems
The system was designed to supply power to critical parts of the security system in the case of a primary source failure.

17.11 Key and Lock Program
During the 1993 terrorist bombing of the Trade Center fire, police and contractors, all came in the possession of keys to various areas of the trade center. Since it was impossible to recover all those keys a new lock and key system was put in place through the entire World Trade Complex.

17.12 Electronic Park Access Control System
This system had three levels of security. First, the car that entered the garage must have had an electronic tag that associated it with parking rights and the car owner Port Authority ID also must have correspond to the tag number. In time of higher threat the third level required the driver to punch a PIN number into a key pad at his window before entering the garage.

17.13 Dates: Start 1993 Substantial Completion 2001

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Cost of Security Systems

PA JOB #	SYSTEM/ELEMENTS	ACTUAL $ SPENT THRU INCEPTION	COMMENT
CW02-027	Intern Security (Perimeter)	$3,866,000	
CW02-030	Parking Security	$4,354,000	
CW02-032	Office Space Security Systems	$1,640,000	
CW02-053	Permanent Security Program	$44,484,000	
CW02-55	Electronic Parking Access (PACS)	$3,915,000	
CW02-074	Glass Protection System	$379,000	
Total Construction Cost	Security Systems	$58,638,000*	* Not includ Financial Expense & P Overheads

18. Permanent Operations Control Center

18.1 Permanent Operations Control Center Description

The Permanent Operations Control Center (POCC) was constructed on B-1l level of 2 WTC while the Back-up Operations Control Center (BOCC) was installed as a console in the Police Command Center in 5 WTC. The World Trade Center's Permanent Operations Control Center served as a central control point for WTC security, safety and communications functions. The old OCC was located on the B-1 level truck dock between 1 and 2 WTC. The facility includes the old 7—7 Desk area (625 sq.ft) and a portion of the old Police facility (approximately 1,000 sq.ft). An additional 1,600 sq.ft of the old Police Command Center was being utilized as the emergency response center to support the OCC when necessary. These areas sustained heavy damage from the February 26, 1993 blast and required major reconstruction.

After the February 26, 1993 bombing, the OCC was temporarily relocated in the old Market Bar area of the Concourse while a portion of the 7-7 Desk continued to be used for communications, elevator control and several other functions In May, 1993, WT Department requested the Engineering Department to identify a dedicated team to continue development of the project. In September 1993, the Engineering Department was directed to proceed with the design for a new facility on the B-1 level of 2 WTC.

A central Fire Command Station (FCS) was included in the original plans. In order to meet NYC Code requirements, the FCS has been decentralized into four stations in the lobbies of Buildings 1, 2, 4 and 5. The POCC provided only a backup facility. An existing elevator was be used for the POCC.

The new Permanent Operations Control Center cost , with substantial construction complete around early 1999, was approximately $25, 000,0000 (excluding financial expense and overhead charges). It provided: 1) improved performance and monitoring of all major World Trade Center base building complex systems by providing a central command center with the infrastructure necessary to monitor and control all building and emergency systems; 2) provided sufficient flexibility for adaptation to new technology and growth; and 3) provided areas from which to coordinate emergency response activities and brief and communicate with tenants, media, etc.; 4) ensured that no single event impairs critical monitoring and control functions for WTC systems. Most of the pre- 1993 OCC's equipment had been in operations since its inception and was based on twenty-five year-old technology. Other building systems have either been or were in the process of being upgraded. The elevator communications system had been upgraded and CCTV monitoring equipment and new fire command stations have been installed in the lobbies of 1 and 2 WTC. Fire alarm and public address systems were in the process of being upgraded. The new security system also had a desk and was monitored from the Permanent Operations Control Center (POCC). Since all upgraded systems feed into the new POCC it became the central point for monitoring and/or control during emergency situations.

18.2 POCC Systems Monitoring

18.2.1 Design and construction of the physical site

It included support functions comprised a large part of the project cost. Construction of the POCC included the following major cost categories: Architectural (Lighting and General Construction), Electrical (Power, Radio, SCADA Integration, Stentofon), Fire Protection, HVAC, Local Site Security, Plumbing, Telecommunications and the Situation Room (Wall Display). The POCC incorporated five major functional rooms, the Operations Control Room, the Situation Room, the Tenant Liaison Room, the Key Control Room and the Tenant Crises Room. Additionally there were ancillary facilities (rest rooms, pantry, electrical equipment room, computer and communications room, storage rooms and a Resident Manager's Office), a secured Entry way (including sally-port, remote controlled entry to the Operations Control Room and CCTV) and a secured emergency exit.

18.2.2 SCADA Systems in the POCC

Several stand alone SCADA systems were developed, independent of the POCC project, to monitor and control individual building functions within the WTC Complex. The requirements for the POCC project, as they relate to each SCADA system, are diagramed and described below.

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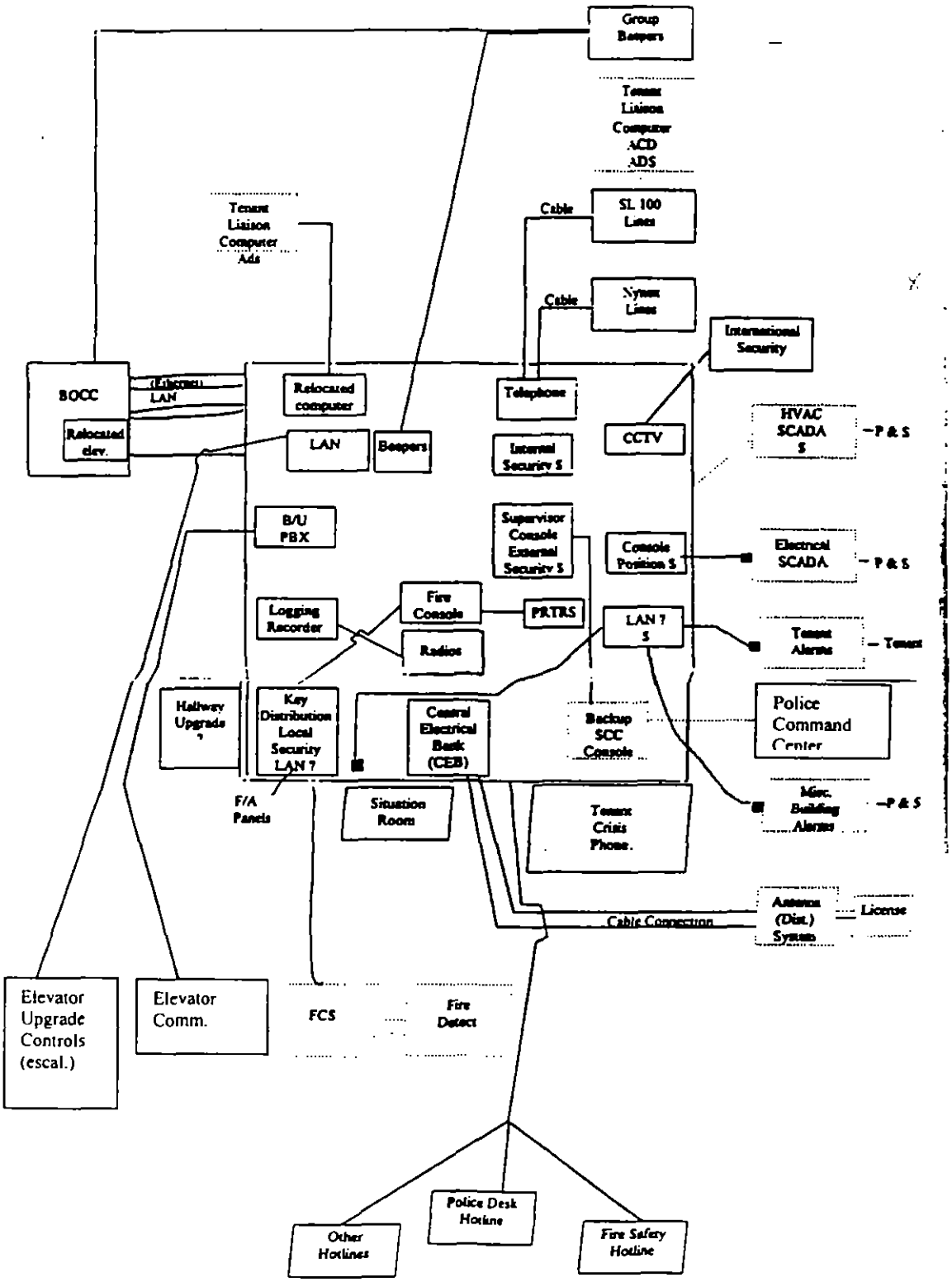
Group Beepers
Tenant Liaison Computer ACD ADS
Tenant Liaison Computer Ads
Cable
SL 100 Lines
Cable
Nynex Lines
International Security
SOCC
(Ethernet) LAN
Relocated comp.
Relocated elev.
LAN
Beepers
Telephone
Internal Security
CCTV
HVAC SCADA
P & S
B/U PBX
Supervisor Console External Security
Console Position
Electrical SCADA
P & S
Logging Recorder
Fire Console
PRTRS
Radios
LAN ?
Tenant Alarms
Tenant
Hallway Upgrade
Key Distribution Local Security LAN ?
Central Electrical Bank (CEB)
Backup SCC Console
Police Command Center
F/A Panels
Situation Room
Tenant Crisis Phone
Misc. Building Alarms
P & S
Antenna (Dist.) System
License
Cable Connection
Elevator Upgrade Controls (escal.)
Elevator Comm.
FCS
Fire Detect
Other Hotlines
Police Desk Hotline
Fire Safety Hotline

- **POCC Construction**

  Design and construction of the physical site, including support functions comprised a large part of the project cost. Construction of the POCC included the following major cost categories: Architectural (Demolition, Lighting and General Construction), Electrical (Power, Radio, SCADA Integration, Stentofon), Fire Protection, HVAC, Local Site Security, Plumbing, Telecommunications and the Situation Room (Wall Display). The POCC incorporated five major functional rooms, the Operations Control Room, the Situation Room, the Tenant Liaison Room, the Key Control Room and the Tenant Crises Room. Additionally there was be ancillary facilities (rest rooms, pantry, electrical equipment room, computer and communications room, storage rooms and a Resident Manager's Office), a secured Entry way (including sally-port, remote controlled entry to the Operations Control Room and CCTV) and a secured emergency exit.

- **SCADA Systems in the POCC**

  Several stand alone SCADA systems were developed by others, independent of the POCC project, to monitor and control individual building functions within the WTC Complex. The requirements for the POCC project, as they relate to each SCADA system, are described below.

  - Elevator SCADA

    A console at the POCC was capable of monitoring and controlling the Elevator SCADA system. Three Elevator consoles were installed in the POCC. These were the Elevator primary control locations. One console was for WTC1 (Tower A) elevators, a second for WTC-2 (Tower B), and the third for WTC-4 and WTC-5. Requirements for monitoring and control consist of data such as: on/off status, position, direction, speed, wind speed, floor lock-out, and a variety of data for statistical analysis. The IBM mainframe application, Elevator Escalator Monitoring Information system (EEMI), were also be accessible from the POCC.

    The Elevator SCADA system was in ongoing construction, with A.C.E. Elevator Company, Inc. (A.C.E.) as the general contractor on a 5 year contract, with two 5 year renewal options to modernize and maintain the elevators in the WTC complex. The sub-contractor responsible for the elevator SCADA system was CEC (Computerized Elevator Controls). The elevator SCADA was connected and configured onto the POCC network as part of the POCC project.

  - Escalator SCADA

    This system provided a console at the POCC capable of monitoring the Escalator SCADA system. A.C.E. was the general contractor for

the escalator upgrade project, was completed by mid 1996, with Elevator Performance Technologies, Inc. (EPTI) as the sub-contractor. The escalator SCADA system was not used to control escalators remotely, but only monitored conditions such as status and direction. Control of the escalators was only done locally. The escalator SCADA system was connected and configured onto the POCC network as part of the POCC project.

- Electrical SCADA
  Electrical SCADA system at the POCC was capable of monitoring and controlling the. Primary control for the electrical sub-stations was provided in the Electrical Shop, with backup in the POCC. The electrical SCADA system was connected and configured onto the POCC network as part of the POCC project.

- Mechanical SCADA
  The Mechanical SCADA system included an HVAC System (Heating, Ventilation and Air Conditioning). SCADA had major Heating, Plumbing, Air Handling and Refrigeration sub-systems. This SCADA system was not connected nor configured onto the POCC network as part of this project, but as part of the HVAC upgrade. The scope and design of the HVAC system was defined, connected and configured onto the POCC LAN. The requirement was to provide a LAN capable of interfacing with a future HVAC system and provide an HVAC console at the POCC that can monitor and control the systems. The HVAC renovation included the Heating, Plumbing, Air Handling, and Refrigeration sub-systems. A console was provided in the POCC to be used by the mechanical operator(s), to monitor and control these various HVAC sub-systems in the WTC Complex, as they came on line.

- Fire Alarm SCADA
  The fire alarm station in the POCC was designed under a separate contract by others, and was presently being installed using a Pyrotronics Cerberus system. The POCC configuration included six redundant remote interfaces for the Fire Alarm Systems in Buildings 1, 2, 4, 5, the subgrade and the concourse, including telephones for all six areas. Monitoring of these systems was permitted from the POCC at all times. However, unless approval was granted on an incident by incident basis, by the NYC Fire Department, or unless control was relinquished by the primary control center in the building lobby, the fire alarm systems were not capable of being remotely controlled.

- Fire Alarm Testing (Greenbase)
  Fire Alarm Testing was a continuous program that involves the testing of the fire alarm end points and connections. It was a task performed by an individual not responsible for monitoring any other systems. A console was provided for this purpose in the POCC as part of this project.

- Network (LAN) for the POCC
  The individual SCADA systems (Elevator, Escalator, HVAC, etc.) could not be operated from the POCC or from any other workstation on the network; unless the used unless an appropriately authorization user required to monitor and control a systems. The LAN located to the POCC was a pair of reversibly routed, redundant Fiber Optic Cables connect the two servers together the servers operate on Novell NetWare SFT for mirroring of all processing and databases. The LAN design satisfied the requirement that individual SCADA systems be able of operating as standalone systems throughout the WTC complex, as providing the capability to monitor and control the SCADA systems consoles in both the POCC and the BOCC.

- Operations Control Room
  The Operations Control Room was the heart of day-to-day operations of the POCC. It contained the Supervisor's console and other control consoles with all the necessary hardware, software and communications equipment to monitor and operate the primary building and life safety services of the WTC facility. This included the SCADA systems (Elevator, Escalator, Electrical Mechanical, Fire Alarm and Fire Alarm Testing), the Backup Port Authority Police Command Center and the Backup Security Command Center.

  The Supervisor's console consisted of two workstations and additional workspace for its crew. From any of the workstations, users were able to monitor and control any of the SCADA systems, as permitted by their logon identification code to each SCADA system. In addition, all necessary communication equipment was provided including: telephones, Stentofon, radio controls for NYC fire, PATH Police, NYC Police, EMS, and NYC Transit Police; sallyport entry controls; intercom system; CCTV camera controls; security and a duress alarm. Start-up / shut down controls for the BOCC were also provided on the console. The BOCC Supervisor's console was a duplicate of the POCC Supervisor's console, and was be located in the Police Command Center.

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The Control console consisted of multiple workstations with workspace for the SCADA operators, the Fire Alarm operator, the Fire Alarm Testing operator, and a Police Command operator. All necessary communication equipment was also provided. As with the Supervisor's console, users were able to monitor and control any of the SCADA systems from any of the workstations, as permitted by their logon identification code to each SCADA system. For operational reasons, however, certain workstations were dedicated to specific systems.

- Situation Room

  The Situation Room was a modern, state of common usage, communications center capable of voice and/or video conferencing with all primary command and control personnel throughout the WTC Complex, JSTC Police and local city emergency centers. It provided a workspace, communications equipment and a display system for senior staff to assemble and manage events during a crisis situation. The display system was capable of viewing any of the displays from the Supervisor's console and the Control Consoles, including computer SCADA displays, CCTV video from all security cameras, and cable Television news channels such as CNN. Because the POCC served as a crisis during times of emergency, all communications systems provided additional resources to achieve diversity and redundancy protection from common single point of failure.

  Diversity and redundancy for voice communications was achieved by providing duplicate access from all POCC locations to both the Northern Telecom SL PBX (located in the WTC) and to NYNEX. Dual sets of 56kbs circuits provided for continuous access to OA, IBM and the JSTC PATH police. Optical fiber interconnected the POCC and BOCC to ensure continuous operation and data synchronization between the dual set on the POCC LAN.

- Access Control to the POCC

  Access to the POCC was monitored and controlled by the WTC Permanent Security System. Major system components included mechanical or electrical locks on all doors; proximity and magnetic strip card readers on entry doors; a sally-port entrance to the facility (complete with card readers, intercoms, CCTV cameras, and a video badge reader to provide a split screen comparison of video badge image and photo ID); duress buttons in the control room and key control room, magnetic door sensors on all perimeter

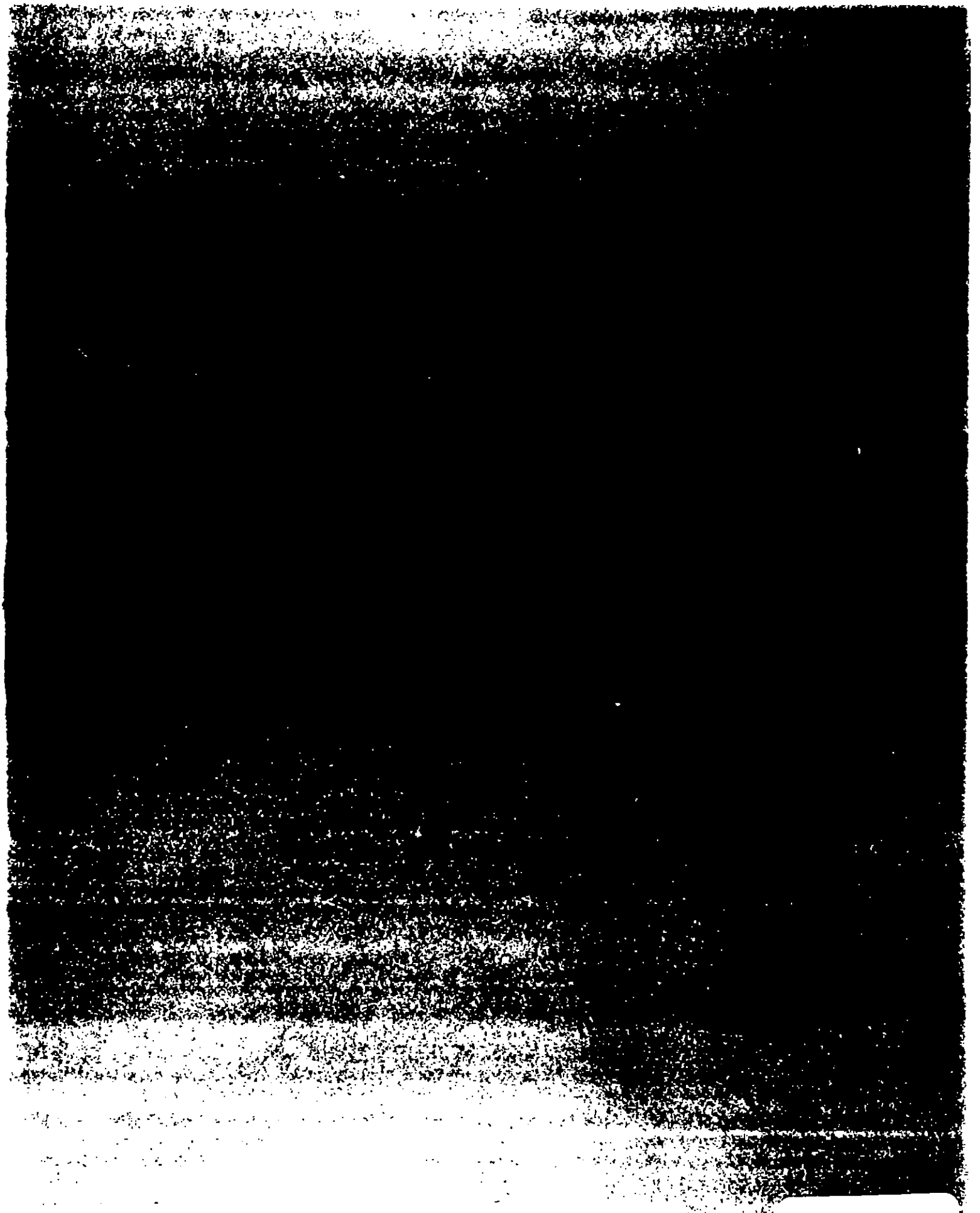
and security sensitive doors to alarm when open; along with color CCTV cameras, monitors and VCRs.

Dates: Start 1996 Substantial Completion 1999

Cost of Operations Control Center

PA JOB #	*SYSTEM/ELEMENTS*	*ACTUAL $ SPENT THRU INCEPTION*	*COMMENTS*
CW02-025	Operations Control Center	$11,177,000	
CW02-047	HVAC Performance Monitoring	$350,000	
Total Construction Cost	Operations Control Center	*$11,527,000**	* Not including Financial Expense & PA Overheads

19. Port Authority Maintenance Programs/Policy

The Port Authority's Maintenance Policy could best be described as preventative maintenance. This approach was characterized as a high-level of redundancy, high quality system components and the replacement of system components before the end of their useful life.

To explain, the theoretical life of a bearing is 7 years continuous operation. Most mechanical systems in the Trade Center had enough redundancy to facilitate their replacement before the end of their useful life. Bearings and impellors in virtually all pumps were replaced before the seven year mark and thus, before they failed. Another example, fans, did not have the same level of redundancy, as pumps mainly due to installation space constrains. However, in 2000, the contractor, AWL, replaced 90% percent of all fans, well before the, end of their useful life. Another example is the electrical systems that were designed for second contingency operation and provided with high quality electrical equipment. They operated at low temperatures, well below their nominal rating thus, preserving the integrity of the insulation systems and extending the useful life of the equipment. In fact, we believe, after long consultation with our other Trade Center experts, that the major systems were constructed with redundancy and/or of equipment of high levels of reliability. It is our professional opinion is that most new buildings are not designed, constructed and operated with these high levels of redundancy, quality of equipment and intensive programs of preventative maintenance.